DOCUMENT RESUME

ED 244 506 EC 162 826

AUTHOR Lamberts, Frances
TITLE Developmental Memory Span for Familiar Auditory Stimuli: Salience of the Perceptual Sign and the Linguistic Symbol. [Final Report].
SPONS AGENCY Bureau of Education for the Handicapped (DHEW/OE), Washington, D.C.
PUB DATE 28 Feb 79
GRANT G007700457
NOTE 93p.
PUB TYPE Reports - Research/Technical (143)

EDRS PRICE MF01/PC04 Plus Postage.
DESCRIPTORS Elementary Secondary Education; *Memory; *Moderate Mental Retardation; Perception; *Recall (Psychology); *Severe Mental Retardation; Short Term Memory; *Stimuli

ABSTRACT

The study, a comparison between moderately and severely mentally handicapped children, and nonhandicapped children, explored memory span over the developmental age range of 3-6 years. A batch-processing adaptation of a task involving auditory-visual matching was used. Age effects and effects of stimulus mode on recognition ability and span were the factors of principal research interest in repeated-measures, factorial designs. In both studies, retarded Ss were found to perform as well as the nonretarded Ss when the stimuli were perceptual but significantly less well than nonretarded Ss when the stimuli were linguistic. Findings supported the hypothesis of memory span growth with age but suggested that the batch-processing recognition procedure may not be the best approach to studying memory. (Author/CL)

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DEVELOPMENTAL MEMORY SPAN FOR FAMILIAR AUDITORY STIMULI: SALIENCE OF THE PERCEPTUAL SIGN AND THE LINGUISTIC SYMBOL

[Final Report]

A Report to the

Bureau of Education for the Handicapped

on

Grant Number C007700457

Project Number 443AH70080

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Frances Lamberts

February 28, 1979

EC162826

SUMMARY

This document is a report on the second of two comparative studies involving moderately and severely mentally handicapped, and nonhandicapped young children. The retarded children were matched by mental age to the chronological age of the nonretarded children. The first study, involving 95 subjects, explored recognition ability for auditory stimuli for familiar events, when the stimuli were presented in a perceptual mode (environmental sounds) and in a symbolic-linguistic mode (spoken words). The second study, with 60 of the same subjects, explored auditory memory span over the three-to-six developmental age range. Auditory-visual matching to sample was the task in the first study; the second utilized a batch-processing adaptation of the same task. Age effects and effects of stimulus mode on recognition ability and span were the factors of principal research interest in repeated-measures, factorial designs. In both studies, the retarded subjects were found to perform as well as the nonretarded children when the stimuli were perceptual but significantly less well than nonretarded children when the stimuli were linguistic. Implications for retarded children's language learning were discussed. The desirability of development and refinement of nonverbal methods in research on retarded children's auditory-cognitive processes was emphasized.

ABSTRACT

It was the intent of the two studies funded under this grant to explore certain characteristics of the cognitive processing of meaningful auditory stimuli by young nonretarded children and severely and moderately mentally handicapped students. The first study investigated their ability to recognize the auditory stimuli for 49 familiar experiential events, when the stimuli were presented as perceptual signs (environmental sounds) or as linguistic symbols (spoken words), and when recognition was measured by an auditory-visual, matching-to-sample task. The present study investigated their ability to recall sequences of two, four, and six of these stimuli, when recall was measured by a batch-processing adaptation of the matching-to-sample task. The specific research questions in this study concerned: (a) growth in memory ability over a three-year, developmental age span; (b) differences in memory span relating to mode of stimulus presentation; and (c) differences in memory performance relating to presence or absence of mental handicap. A repeated-measures design was utilized in which developmental age and group were the between-subjects factors, and stimulus presentation mode and sequence length the within-subjects factors.

Sixty subjects participated in the study. Of these, 25 were nonhandicapped three through five year old children in regular nursery and Kindergarten classes, 35 were students in public school classes for the moderately and severely mentally handicapped. The mentally handicapped students ranged in chronological age from approximately 8 1/2 to approximately 20 years. Their mental age, as measured on the Stanford-Binet or WISC scales, was comparable to the chronological age of the nonhandicapped children.

Factorial analysis of variance revealed strong age trends in memory span performance. The age factor did not interact with either the group or the stimulus-mode factor. Absence of an age interaction indicated that: (a) the severely mentally handicapped and the young nonhandicapped children showed similar developmental growth in short-term memory span;

and (b) that such growth was similar for stimuli which are perceptual and for stimuli which are symbolic-linguistic in nature. An important finding, however, was seen in a significant stimulus mode by group interaction. The mentally handicapped students achieved comparable scores to the MA-matched, nonhandicapped children when the stimuli were perceptual. Their performance was significantly inferior to the nonhandicapped childrens' when the stimuli were linguistic. A strong overall depression of recall scores was noted as compared to the span scores typically reported, when children of comparable ages are tested with other short-term memory procedures. The batch-processing task appeared to be more detrimental to recall performance for the nonhandicapped than for the handicapped students, resulting in an increase in the latter's recall scores as the trial sequences increased in length. As in other memory research, greatly elevated response times were obtained for the retarded, relative to the nonretarded students.

The most significant finding from the study concerned the ability of severely and moderately handicapped learners to process perceptually coded stimuli for familiar experiential events as successfully as nonhandicapped young learners. This ability was interpreted as revealing an aspect of severely handicapped learners' cognitive competence which has not been investigated before and which, unfortunately, remains relatively untapped in instructional intervention efforts with such students. The retarded students' impairment, relative to nonretarded children, in ability to process linguistic symbols for the same events was related to theories of a critical age for language acquisition. Whereas other researchers have suggested that a fundamental, auditory-perceptual dysfunction, even auditory agnosia, may underlie severely mentally handicapped persons' language impairment, the results from the two studies conducted under this grant indicate that this may not be the case for most such persons.

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INTRODUCTION

Rationale

The principal theoretical background for the present study derived from propositions raised in imagery research, namely, that concrete, "perceptual" stimuli such as pictures or objects, and "picturable" concrete words are easy to learn and remember. They are considered memorable because of the "rich detail" of sensory associations which relate them to particular times, places, and circumstances in the learner's experiences. It has been asserted that preschool children should benefit particularly from perceptual stimulus representation, since their mode of experiences and knowing is presumed to be directly tied to perception (Bruner, 1964; Olson, 1973).

Two biases have pervaded past study of the cognitive functions of the retarded. First, most research has been concerned with subjects at the mild or borderline levels of retardation. Lower functioning persons' mental processes were studied infrequently. This fact undoubtedly reflects both the respective prevalences of mildly and severely handicapped persons and methodological difficulties inherent in research with the latter. However, a resultant problem is that assumptions about learning processes of the severely retarded must often be based on extrapolation from research findings with the less handicapped. Such extrapolation is a factor which affects the validity of mental retardation research (Brooks & Baumeister, 1977). Second, perceptual and memory processes have been studied primarily in the vidual mode, and their study in the auditory mode has been neglected. The major theories and research efforts which attempt to account for retarded persons' memory functions have developed visual methodologies almost exclusively (e.g., Butterfield & Belmont, 1972, 1977; Ellis, 1963, 1970; Scott, 1971). The contribution of the auditory modality in retarded, as well as in nonretarded children's learning and memory, has been considerably ignored (Davis, 1978).

The importance of memory ability to language has often been pointed out. The fleeting nature of the speech stimulus demands that it must be held in a short-term store while later portions of the message unfold. Sentence

constituents must be kept in memory before their semantic message can be attained (Crowder, 1976). Olson (1973) observed that "without temporary storage there would seem to be no way we could speak or understand the speech of others" (p. 146).

It was easy to postulate a link between memory ability and children's language growth. Miller (1951) thought it likely that the child learns syntax partly by remembering the order of words. In more recent child language research, the coincidence of growth in utterance length and growth in memory span has been noted (Brown & Fraser, 1963). The likelihood of a causal relation of the latter to language acquisition has been argued by Bloom (1970), McLean and Snyder-McLean (1978), and Slobin (1970). In children with delayed language development, limitation of auditory memory is often observed (Masland & Case, 1968). In retarded children, the pattern of severe impairment in both language and memory ability may also suggest a causal link.

In the present research, growth in auditory memory span was explored in young nonretarded children who are rapidly acquiring the grammar of language and in severely retarded children who have largely failed to do so. The research is unique in several aspects. First and foremost, it is unique in extension and refinement of a methodology introduced by Heffner (1974) and Lasky, Jay, and Hanz-Ehrman (1975) to include a wider variety of auditory stimuli. The second unique contribution lies in its application to studying memory span among the severely retarded. Peterson (1977), Olson (1973) and others have urged use of nonverbal stimuli in research with children so that evaluation of memory capacity may not be confounded by expanding linguistic ability. Third, while direct comparisons of linguistic and perceptual stimuli, with both retarded and nonretarded learners have been undertaken in the visual mode, such a comparison has not been done in the auditory mode. Fourth, moderately and severely mentally retarded children were studied who were not additionally encumbered by an atypical, institutional environment. In the past, learning research with the severely handicapped has often suffered from external-validity limitations because of this encumbrance (Baumeister, 1968).

In linguistics and information science, some theorists (e.g. Whatmough, 1956; Dance, 1967) have characterized nonlinguistic and linguistic meaningful stimuli, respectively, as "sign" and "symbol" to denote the nature of their relation to the events which they typify. A nonverbal stimulus is a sign of its event inasmuch as it is an impression perceived through the senses which is inherently a part of the event and is necessarily present when the event is present. A word is a symbol for its event, inasmuch as it is an arbitrary designation which does not bear a necessary temporal or causal relation to the object or event it refers to. This nomenclature was adopted in the present research. The stimuli were realistic environmental sounds (signs) and words (symbols), and both stimuli represented the same experiential events. The questions of significance for this study were whether one type of stimulus may mediate recognition memory-span performance more effectively than another, and whether the relationship between sign and symbol changes with age.

Auditory Short-Term Memory

When the human being is considered as a processor of information, it is necessary that he have available mechanisms or stores to hold incoming information temporarily so that it can be acted upon. Such holding mechanisms are particularly important for the processing of auditory information which is received piecemeal and serially. Portions of it must be held if perception of dimensions and patterns in the incoming stimuli is to be possible. Scott and Scott (1986) pointed out that

> in a simple discrimination, memory for what happened on the last trial plus what was reinformed seems clearly required for learning. In a more complex problem, to detect a dimension, strategy, or rule, memory for a sequence of trials is frequently required. The empirical fact that memory span is limited suggests that an individual with a brief span may lose much incoming information before he can process it into (long-term memory) (p. 136).

Craik and Lockhart (1972) stated that the most widely accepted view considers memory storage to consist of three levels: (a) a sensory or pre-categorical store, (b) a short-term or immediate-memory store, and (c) a long-term store. Some theoretical models of memory have further postulated a division of the short-term store into primary and secondary memory components (Waugh & Norman, 1965). The primary component is identified with the two or three items typically recalled in the recency portion of the serial-position curve. The secondary component is identified with the items recalled in the primacy portion of the curve and is thought to reflect rehearsal. The multi-process model has been influential in theories of retarded persons' memory processing (Ellis, 1970; Belmont & Butterfield, 1971) but has been criticized because of an implied discontinuity in the temporal course of information-processing events (Wickelgren, 1973).

Definition of Short-Term Memory

Short-term memory, also termed immediate memory or memory span, is defined by the length of the series of stimuli which a subject can typically reproduce immediately after presentation (Crowder, 1976). Adults characteristically have a span of seven or eight items. Stimulus items in the short-term store are subject to rapid decay; unless rehearsed, they become indistinct and fade as a function of time. Estimates of the time during which unrehearsed items remain available in the short-term store vary from five to 30 seconds. Within 30 seconds or less, however, forgetting from the short-term store is complete (Craik & Lockhart, 1972). Olson (1973) gave a "functional" definition of immediate or short-term memory as the limited capacity store which represents a first state of processing after item perception and before higher-order processing, and which "is largely oriented toward preserving transient features of the environment long enough so that relatively slow mental processes have a chance to operate upon environmental input" (p. 146).

Development of Memory Span

Memory span increases systematically in the developing child. The increase is so reliably related to chronological age that digit span is one of the basic measures of child intelligence tests. Memory span in normally

developing children is: two items at two and one-half years of age, three at three years, four at four and one-half years, between four and five at six years, and between seven and eight items (adult span) by age 16 (Huttenlocher & Burke, 1976).

Short-Term Memory in the Retarded

A number of researchers have suggested that the memory deficits of the retarded may be limited to immediate memory. Specifically, Spitz (1966) has asserted that characteristics of the sensory stores of retarded and nonretarded persons are similar. Belmont (1966) has demonstrated that retarded subjects' long-term retention does not differ substantially from nonretarded subjects'. Thus, the limiting deficit appears to lie in capacity or strategies related to immediate memory.

Figure 1 illustrates the consistent finding in comparative short-term memory research. For retarded individuals, short-term span appears to be limited to approximately three items, while nonretarded persons recall, with increasing age, up to seven items. Span limitation in the retarded has been documented with a variety of tasks. For example, the curves in Figure 1 summarize the findings from Ellis' studies in which the task involved memory for position of digits presented visually. In a study by Frankel and Tymchuk (1974), the task was serial recall of digits presented orally. The retarded subjects' mean recall was four digits at fast presentation rates, three digits at a slow rate. In an elicited imitation study by Lamberts and Burns (1979), the task was recall of words presented orally. Approximately 30% of a group of severely retarded subjects could not reproduce more than two words. In the study by Walker, Roodin, and Lamb (1975), moderately retarded subjects achieved a mean serial digit recall of 2.10 digits at mental age 6 to 6 1/2 years. It is important to note that significanly inferior span performance by the retarded has been documented in a number of studies when compared to nonretarded children, even when matched on mental age (e.g., Frankel & Tymchuk, 1974; Gerjuoy, Winters, Pullen, & Spitz, 1969; Hermelin & O'Connor, 1964; Walker et al., 1975).

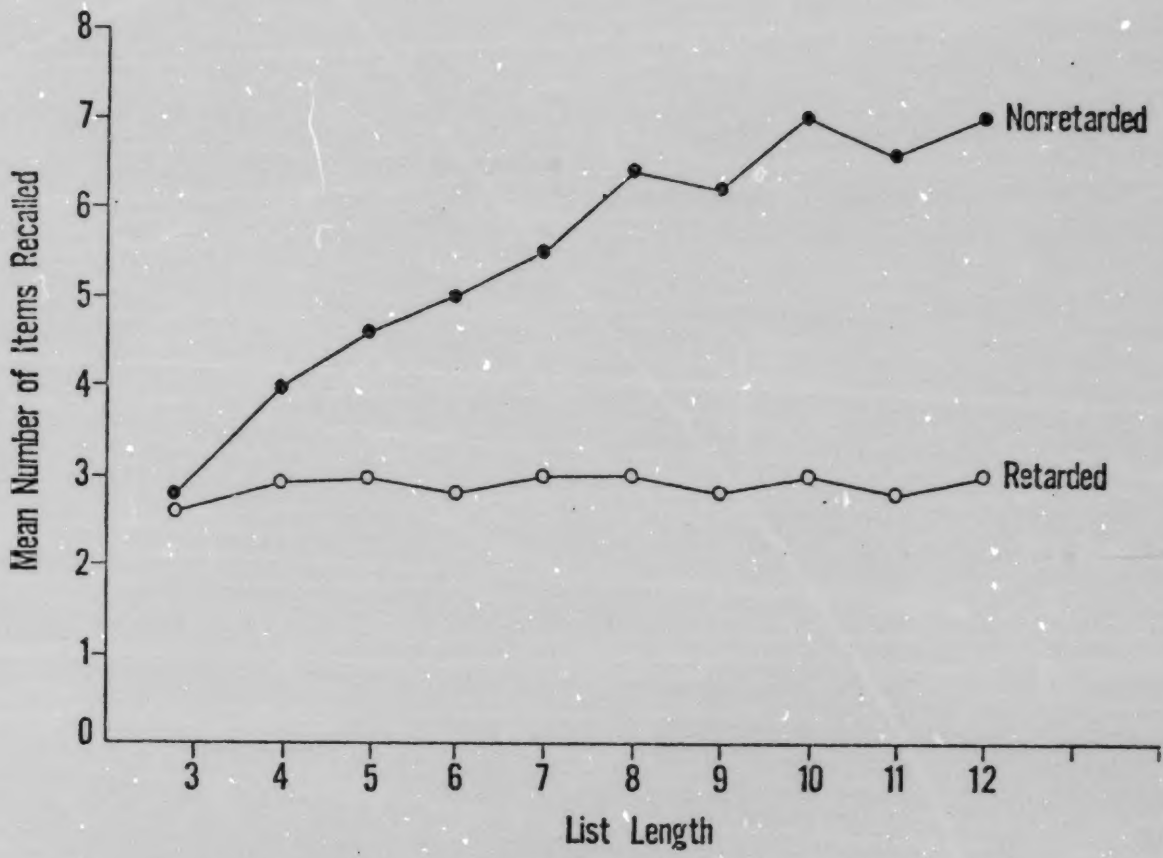

Figure 1 Total retention for retardates and normals over tasks of varying length. (From: Ellis (1970), as reported in Mercer & Snell, Learning theory research in mental retardation, 1977, p. 16.)

Hypothesized Reasons for Span Deficit in the Retarded

Two major reasons have been advanced to explain retarded persons' low memory span performance. They may be summarized in the general statement that the retarded person is seen as a relatively passive information processor. Normal children, and adults, engage in active mnemonic strategies during learning and retention, e.g., by overtly vocalizing, rehearsing, and categorizing incoming information. The retarded are thought to make little deliberate effort to use such strategies (Kellas & Butterfield, 1971; MacMillan, 1972). Ellis, and Belmont and Butterfield have been most explicit in delineating an assumed process deficit, i.e., that the retarded fail to rehearse information in the short-term store; therefore, its trace is quicly lost. This hypothesis was suggested by observations that retarded persons' recall did not differ in the recency portion of the serial-position curve but did differ on medial items and, particularly, on the primacy portion of the curve. Ellis, and Belmont and Butterfield also obtained direct evidence of lack of rehearsal by the retarded. For example, Ellis (1970) found that, when stimuli were presented with either a two-second inter-stimulus interval versus no interval, the former condition produced significantly better recall in nonretarded subjects but did not affect the retarded persons' performance. Retarded persons, presumably, did not make use of the interval for rehearsal. When Belmont and Butterfield (1969, 1971) allowed subjects to pace themselves, non-retarded subjects slowed stimulus presentation as lists grew longer, while retarded subjects exposed all the lists at the same pace.

Both in the general experimental and in the mental-retardation literature the importance of rehearsal, per se, as a crucial factor in short-term memory performance has been questioned. For example, ingenious experiments by Craik and Watkins (1973) and, particularly, by Woodward, Bjork, and Jongeward (1973) demonstrated that amount of time spent in deliberate and motivated rehearsal may have no effect on recall performance. Turnbull (1974), who trained retarded subjects in cumulative overt rehearsal in a visual probe memory task and hypothesized that primacy items should benefit most from the rehearsal found this expectation unconfirmed. Recall gains were, instead, evenly distributed over all serial positions, thus failing to support the Ellis model. Even more

damaging evidence was Frankel and Tymchuck's (1974) finding that, when digit strings were presented at a rate of four per second, both retarded and non-retarded subjects showed better recall than when they were presented at the rate of one per three seconds. Clearly, however, according to Ellis' model, the slow rate provided opportunity for rehearsal while the fast rate did not.

Spitz, among others, has suggested an explanation of retarded individuals' immediate memory deficit which is influential and has been researched extensively, with a wide variety of tasks. Spitz (1966) has hypothesized that the retarded may feel overwhelmed by the chaotic mass of stimuli which surrounds them and fail to effectively impose organization on these stimuli, which would reduce information load. As a result, Spitz argued, their processing capacity is overloaded. They have a memory defect

> because of a deficiency in categorizing the mass of incoming data into a few large chunks; they are simply overloaded . . . The question is not whether or not retardates group or organize materials, but rather under what condition, in what manner, and how efficiently they display this capacity. Retardates may include too few stimuli in a category, or too many . . . (p. 36),

and

> a primary difference between . . . retardates and normals is the speed and manner in which retardates scan and selectively organize the material for storage. Chaotic input makes for chaotic retrieval (1973, p. 157).

Given the importance of both experimenter-imposed and subjective organization of stimulus material on recall, as documented in the experimental literature (e.g., Cofer, 1965; Gardiner, Craik, & Birdwhistle, 1972; Mandler & Pearlstone, 1966), it is not surprizing that Spitz' theory has spawned extensive research. Twenty-seven studies conducted between 1966 and 1974, with digit-, object- or picture-, and word-stimuli were listed by Mercer and Snell (1977). Studies continue to be reported which explore retarded individuals' use of grouping processes in the encoding of stimulus input, and to train them in grouping strategies for better recall (e.g., Glidden, 1976, 1977; Holden & Winters, 1977; Reichhart, Cody, & Borkowski, 1975). The results of

many studies in which retarded learners are taught to rehearse and/or chunk the input appear to bear out the contention by Baumeister and Kellas (1971) that training on active acquisition strategies enhances information retrieval in retarded persons. Although it has generally been held that memory span is a developmental function which is relatively unaffected by training, digit-span increases up to the normal levels for chronological age were recently reported to have been achieved, through rehearsal training, with three Downs syndrome children (Farb, Cottrell, Montague, & Throne, 1977). These researchers considered it possible that further successful demonstrations of the trainability of retarded persons' memory may justify " a reconsideration of the long-held assumption that mental retardation is essentially irreversible" (p. 135). Indeed, substantial evidence is being accumulated, in contemporary research efforts, that fundamental cognitive modifiability of the retarded learner may be attainable through suitable training in basic mental processes (Call & Switzky, 1975; Feuerstein, 1977; Friedman, Krupski, Dawson, & Rosenberg, 1977; Haywood & Switzky, 1974).

Summary and Statement of the Research Questions

It appears that only recently has research been undertaken to attempt to identify direct links between perceptual-learning and memory handicaps in the retarded, and their low performance in language. Heffner's (1977) finding of symptoms of auditory agnosia in retarded children with severe language impairment, and Walker, Roodin, and Lamb's (1975) finding that digit span is the highest predictor of expressive ability in moderately retarded children may be cited as examples. Though there is extreme paucity of relevant studies, cognitive developmental and psycholinguistic theories suggest the importance of perceptual-learning and memory abilities to language acquisition.

Study of auditory perception and memory has been neglected with both non-retarded and retarded learners, and with children during the age when these abilities are developing. Lack of research with nonverbal and, particularly, meaningful nonlinguistic stimuli has been recognized and the desirability of their use in leraning research with children has been urged (Olson, 1973: Peterson, 1977).

In the present research perceptual and linguistic stimuli were employed in an auditory memory task, with retarded and nonretarded learners of similar levels of mental development. From the attention-deficit theory of Zeaman and House (1963), the input-organization theory of Spitz, and Heffner's finding, the prediction was made that possible performance differences between retarded and nonretarded learners would be greater for perceptucal than for linguistic stimuli. That is, retarded children's memory span for perceptual stimuli was expected to be more discrepant from the nonretarded children's performance when the stimuli were perceptual than when they were linguistic.

The overall research questions may be stated as follows:

1. Does auditory memory-span performance increase with developmental age in the three-to-six-year range?

2. Does auditory memory-span performance differ when the stimuli are perceptual or when they are linguistic?

3. Do nonretarded children of ages three to six years, and moderately and severely retarded learners of comparable developmental ages, perform similarly on the auditory memory-span task?

METHOD

Design

A batch-processing adaptation of a sound-and-picture matching to sample task was used. Children chose a sequence of pictures from picture arrays to match a sequence of auditory stimuli.

Stimulus presentation mode, population, developmental age, and sequence length were the independent variables in a repeated-measures, analysis of covariance design. There were three dependent variables: computed scores for (a) number of items correct at each trial, (b) items correct in sequence, and (c) response time. Three levels of age (three, four, and five year developmental age) and the two populations were the between-subjects main factors. Stimulus presentation mode and sequence length were the within-subjects main factors. Scores from the earlier, stimulus-recognition study, were the covariates.

All subjects received 15 trials in each presentation mode, five trials each at sequence lengths two, four and six. Half the subjects in each group received the linguistic stimuli first followed by the perceptual stimuli; for the other half the order was reversed.

Subjects

The subjects were 60 students enrolled in public schools. Thirty-five subjects attended suburban public schools for the trainable and severely mentally handicapped. Twenty-five subjects were nonretarded children in regular suburban, Kindergarten and nursery classes.

The mentally handicapped students ranged in chronological age from 8.42 to 20.75 years. Their mean CA was 14.58 years, with an SD of 3.25 years. The nonretarded children ranged in chronological age from 3.17 years to 5.38 years. Their mean age was 4.42 years, wtih an SD of nine months.

The retarded students ranged in mental age from 3 to 5.67 years, with a mean MA of 4.17 years and an SD of nine months. IQ's of the retarded students ranged from 22 to 54, with a mean of 37.8 and an SD of 6.6. All psychometric evaluations were based on the Stanford-Binet Intelligence Scale or the Wechsler Intelligence Scale for Children, and all had been administered within two years prior to this research. (Developmental age levels were defined as follows: 36 to 47 months = three years, 48 to 59 months = four years, 60 to 71 months = five years.) The retarded and nonretarded groups were closely matched for developmental age. That is, the mean mental age of the retarded group was comparable to the mean chronological age of the nonretarded group at each developmental level. The retarded students were heterogeneous with regard to etiology.

Psychometric test data were not available for the nonretarded children. Their categorization as nonretarded was made on the basis of regular class placement and absence of any developmental difficulties as reported by their teachers. While the equating of the subject groups on mental age must, therefore, be made with caution, it was felt that large variability in developmental functioning would be reflected in teacher ratings, and would be identified through Kindergarten screening. A number of recent comparative studies have made similar assumptions (cf., e.g., Holden & Winters, 1977; Blackman, Whittemore, Zetlin, & MaNamara, 1977; Walker et al., 1975). In the present study, the term "developmental age" was used instead of "mental age." However, since equivalence of CA and MA in the case of nonretarded subjects was implied, developmental age represents actual chronological age in the case of nonretarded children and measured mental age in the case of retarded students.

Data collection for the present study took place from two and one-half to four months after completion of data collection for the stimulus-recognition study.

Stimuli and Apparatus

The auditory stimulus set was the same as in the stimulus-recognition study, but tapes containing sequences of these stimuli were made. Tapes were prepared by splicing together series of recorded words or sounds. The individual sounds were shortened to a duration of three seconds in order that the longest trials would not exceed maximum duration of short-term memory span. The sounds within a trial were separated by 500 msec of silence. In the perceptual presentation condition, stimulus sequences were at the rate of one sound per 3 1/2 seconds. In the linguistic presentation condition, stimulus sequences were at the rate of one word per 1 1/2 second.

The sequences were derived as follows. The stimuli from each category (i.e., household, animal, people, music, and outdoor noises) were placed into separate piles. The stimuli for a trial sequence were determined by random draw of one from each pile, as many as required by that sequence. (For the trials at sequence length six, two stimuli from one random category had to be used.) The stimuli drawn for a given trial were then re-randomized in order to prevent the possibility of bias from the order of the categories. The resulting trial sequences, five at each sequence length, are shown in Table 1.

For each audio-stimulus sequence, a response slide was prepared from the pictures used in the stimulus-recognition study and some additional, comparable pictures. Response slides always contained twice as many pictures as there were audio stimuli in the trial. That is, the slides showed from four to 12 pictures for the trials of sequence length two through six, respectively. The pictures for the trials at sequence length two were arranged in one row of four on the slides. The pictures for the trials at sequence length four were arranged in two rows of four each, those for the trials at sequence length six in three rows of four each. The stimulus pictures--those which

Table 1

Auditory Stimuli in Recognition Memory-Span Task

Stimuli at each trial						
Trials at Sequence Length 2:						
1.	Drip	cow				
2.	Horn	mower				
3.	Knock	telephone				
4.	Sheep	violin				
5.	Gun	yawning				
Trials at Sequence Length 4:						
1.	Water	coughing	bird	drum		
2.	Horse	bell	rain	whistling		
3.	Train	glass	sneeze	sheep		
4.	Duck	clock	drill	violin		
5.	Walking	guitar	bubbles	whistle		
Trials at Sequence Length 6:						
1.	Piano	cat	thunder	yawning	glass	cow
2.	Siren	music	clap	fizz	cricket	gong
3.	Laughing	church	toilet	dog	parade	gun
4.	Fizz	knock	bird	bell	train	cough
5.	Rooster	hammering	horn	drilling	laughing	door

matched the audio stimuli--always occurred within a left-to-right and top-to-bottom-row sequence, with one exception.[1] Figure 2 illustrates slide layouts. Appendix B-I contains a description of all the slides.

Presentation of the audio and picture stimuli was as in the stimulus recognition study.

Response time for each trial was obtained as follows. When the tape recorder control button indicated termination of the audio trial, the first examiner started a Lafayette Instrument Company Number 5810 Timer which was connected to a Lafayette Number 5804 Data Recorder. The latter was set to record time in tenths of seconds. Timer and data recorder were facing the first examiner, away from the subject. An extension switch was wired to the timer which could be held by the second examiner in her left hand and which she depressed to de-activate the timer. She stopped the timer when the child removed his hand from the screen indicating response completion. The first examiner then read the time off the recorder, aloud, and the second examiner recorded it onto the child's response record. The timer was reset to zero and activated again by the first examiner, as described above, after the next audio trial. Response time thus represents the time children took, from the moment of appearance of the slide, to complete their picture selection.

Procedure

The procedure was the same as in the stimulus-recognition study. The first examiner operated the equipment and monitored trials through a separate set of headphones. The child listened via headsets and sat facing the rear-projection screen. He pointed to the pictures manually, and pacing was

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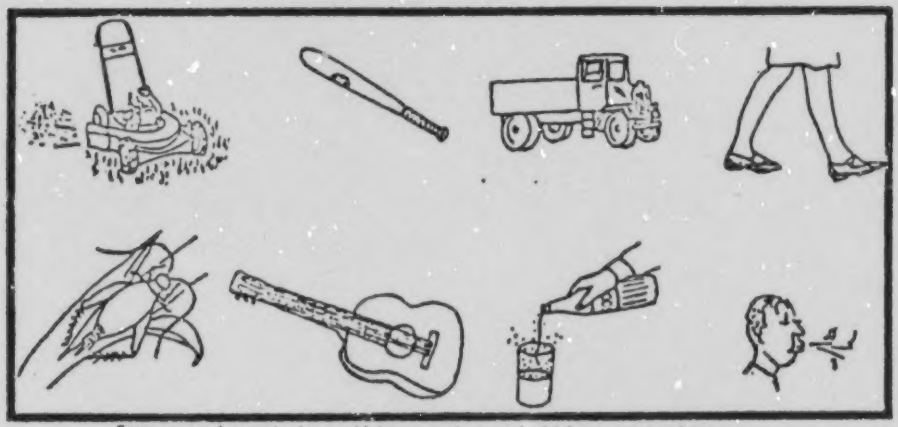
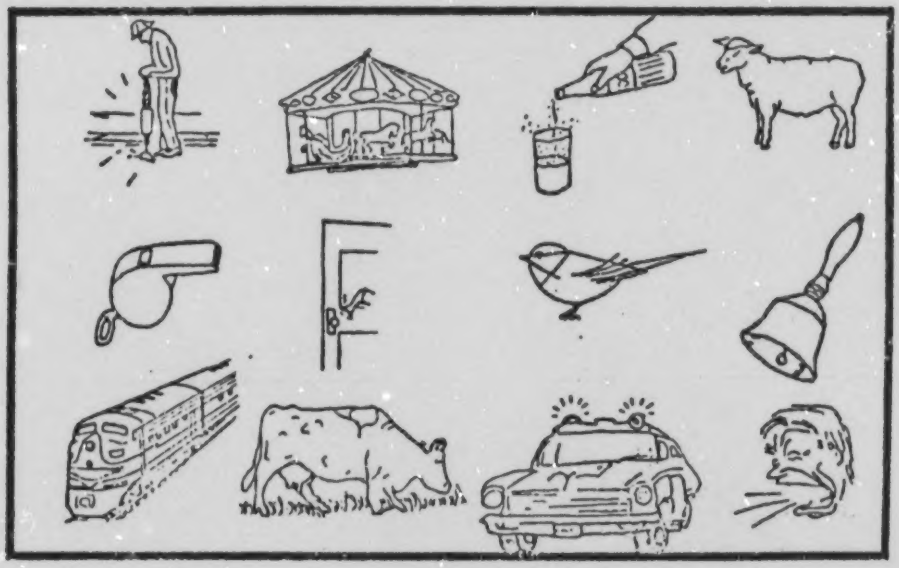
[1] The stimulus materials had been prepared so that the arrangement of stimulus pictures on the slides would be in the indicated order. However, in the implementation of the study, one slide each at each sequence length was presented in reverse, with the result that stimulus pictures on these slides were in right to left order. All children were tested in this manner. The potential effect of presentation of one slide at each sequence length in reverse picture order is considered for further analysis.

Sequence Length 2: knocking, telephone



Sequence Length 4: walking, guitar, bubbles, whistling



Sequence Length 6: fizz, knocking, bird, bell, train, coughing.

Figure 2. Sample slide at each sequence length in the recognition memory-span test; stimulus pictures as indicated.

subject controlled. The second examiner sat to the left of the child and recorded his responses by writing down abbreviated words denoting the picture choices the child made, on a mimeographed recording sheet. The experimental setting is shown in Figure 3; a sample response recording sheet is shown in Appendix B-II.

Instructions were given by the second examiner. The precise wording of the instructions may be seen in Appendix B-III. The following procedure was used to train children for the task.

1. Children were given two practice trials each at sequence lengths two and four, and one at sequence length six.

2. If children selected the correct (stimulus) pictures, and in correct order, they were praised and continued in the test.

3. If on the first two trials children made order but not picture-choice errors, they were verbally corrected for order and listened to the trials again. On training trials after the first two, they were only given verbal correction.

4. If children made picture-choice errors, they were told the correct choices and asked to identify them on the slides. This correction was given for all five training slides.

All children were able to identify at least the stimulus pictures at the shortest sequence length, and all subjects were, therefore, included in this phase.

Nine of the retarded subjects and five of the youngest nonretarded subjects required two sessions in one or both stimulus conditions. All other subjects took the training and test trials for each condition in the same sessions.

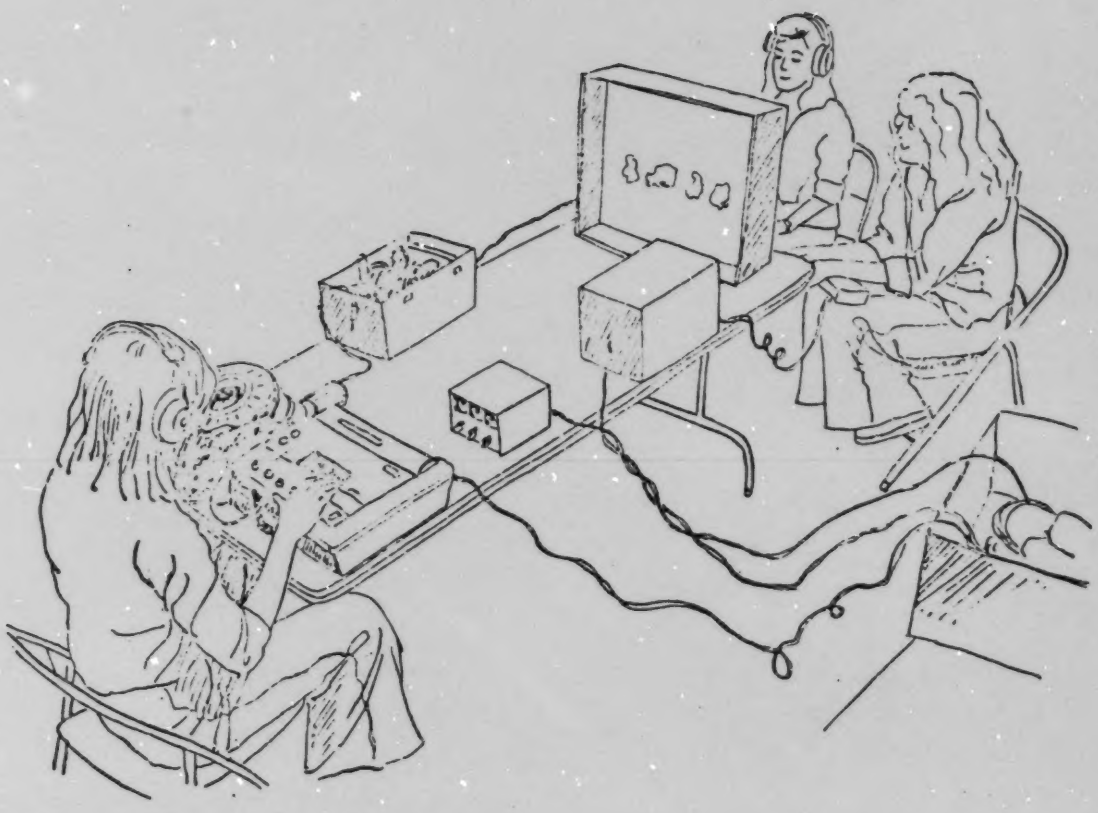


Figure 3. Experimental setting for the recognition memory-span test.

Scoring

All subjects' responses on all trials were transferred onto a scoring sheet for manual scoring. The scoring sheet specified the picture content of each slide and the pictures which represented the correct responses. After writing in the obtained responses, these could be compared against the stimulus pictures and scored for errors. Figure 4, below, shows a portion of the scoring sheet; a complete scoring sheet is shown in Appendix B-IV.

Slide #1:

Contents:	choir	audience	drip	cow
Stimulus:	drip	cow		
Response:				
	o ;	in ;	s ;	e ; ii ;

Figure 4. Portion of scoring sheet to derive the scores in the recognition memory-span study.

Two dependent measures were computed. 1. A simple recall (SR) score represented the number of items correct in any trial, regardless of order or other (e.g., addition, substitution, deletion, inversion) errors. 2. An adjusted serial recall (ASR) score represented the sum of correctly recalled and correctly ordered items in any trial.

The adjusted serial score was derived from a modification of traditional memory-span scoring, in which responses are considered correct up to the first error and all items after the first error are ignored. Huttenlocher and Burke (1976) designed the modified procedure for assessing digit-span performance in children, for whom they considered the traditional scoring inadequate. They

argued that the traditional scoring underestimates children's ability. "If there is an omission or an intrusion, not only that item but all later items are scored as incorrect, even if they are the correct items given in the correct order . . . Such a scoring procedure may not provide a good estimate of what the subject knows about a list of items" (p. 8). The authors' rationale suggests that the modified scoring is suited to recognition-span experiments such as in the present study, for the same reason that it is appropriate for digit-span experiments. They argue that many researchers, in order not to underestimate children's memory ability on account of problematic scoring, have instead used free recall methods. However, while a free recall method may be appropriate for words, it is not appropriate when the universe of items to be reproduced is known by the child. Thus, "since there are only 10 digits, subjects could get most items right . . . by simply counting" (p. 9). The same logic applies to batch-processing recognition tasks, in which subjects likewise could get the items right by simply pointing to all pictures. Huttenlocher and Burke devised the adjusted scoring to both correct for errors that could arise from availability or knowledge of the item pool, and to allow maximum credit for all items reproduced.

In the adjusted scoring procedure, as described by the above authors and as used in the present research, one point was subtracted for each occurrence of the following errors: omission of items, addition or insertion of items, substitution of nonstimulus for stimulus items, transposition of adjacent items, and intralist or distant transpositions. After all such errors were corrected, subjects were credited with one point for each remaining item, and the sum of these represented the adjusted serial recall (ASR) score.

Figure 5 illustrates the scoring. Detailed specification of the scoring method, and more examples, are provided in Appendix B-V. Omission errors were abbreviated as 'o,' intrusion errors as 'in,' substitution errors as 's,' reversal errors as 'e,' and intralist transpositions as 'ii.' In the example in Figure 5, the subject's errors are classified as one intrusion, one substitution, and one transposition.

Slide #11:

Contents:	bat phone clock	truck thunder rooster	t.brushing cat		piano cow	yawn glass
Stimulus:	piano	cat	thunder	yawn	glass	cow
Response:	thunder	truck	piano	cat	glass	cow rooster
	o ;	in ;	s ;	e ;	ii ;	
		truck (or rooster)	rooster (or truck)			

Figure 5. Example of scoring in the recognition memory-span study.

This subject's simple recall score is five for the five correct items; his adjusted recall score is three for six stimulus items minus three errors.

In order to determine scorer reliability, all protocols were scored for SR and ASR by the first examiner. A second person not involved in the research independently scored seven random protocols. Scorer reliability was determined as follows. Each protocol contained 15 SR and 15 ASR, i.e., 30 scores, for a total of 210 on the seven protocols. Percent agreement was derived from the ratio

$$\frac{\text{Total scores} - \text{Disagreements}}{\text{Total scores}} (100)$$

The two scorers differed in 16 items; thus, interscorer reliability was 98.09%.

RESULTS

This section presents the statistical analyses and findings based on the data collected in the memory-span study. The intent of the study was to investigate : (a) age trends in preschool children's auditory memory span when measured with a batch-processing, picture-recognition task; (b) differences in memory span due to the perceptual or linguistic nature of the auditory stimulus; and (c) differences in memory span due to group membership. The research questions were tested by analysis of covariance for repeated measures (BMDP-77; Dixon & Brown, 1977, procedure P2V). One-way analyses of variance, t-tests, and Newman-Keuls tests (Kirk, 1968) were used for follow-up comparisons of significant interaction and main effects.

Raw Data

The raw data from this study are presented in Appendix A. For all 60 subjects, the appendix shows: (a) the simple and adjusted serial recall scores on each trial, under both stimulus conditions; (b) error scores for five error types, summed over the five trials at each sequence length, under both stimulus conditions; and (c) response time summed over the five trials at each sequence length, under both stimulus conditions.

Analysis of Covariance for Recognition Memory-Span Scores

Since the influential hypothesis of Huttenlocher and Burke (1976) considered stimulus recognition to be a major determinant of memory span growth in the preschool years, and since the stimulus sounds and words of the present study were the same as in the earlier, stimulus-recognition study, a covariance approach to analysis of the memory data was deemed desirable. Any possible pre-treatment differences in stimulus recognition between the groups and over different age levels would thus be controlled for in analysis of the memory data.

Covariates were determined separately for each of the 15 memory trials. For each trial, students' summed recognition scores (from the earlier study) were calculated for the stimuli involved in that trial . For example, for

the fifth memory trial containing the stimuli "gun" and "yawning," the covariate was the sum of students' correct responses to items 36 and 38 ("gun" and "yawning") of the stimulus-recognition study.

Number of cases, means, and standard deviations of items recalled (recognition recall) in correct sequential position, at each sequence length and age, are presented in Tables 2 and 3. Table 2 shows these memory data for the linguistic stimulus condition, Table 3 for the perceptual stimulus condition. The data are based on the adjusted serial recall score described under Method, i.e., on subjects' picture-choice responses corrected for errors of addition, substitution, transposition, and omission.

A 2 (Group) x 3 (Age) x 2 (Condition) x 3 (Sequence length) repeated-measures analysis of covariance was carried out, with group and age defining the between-subjects factors and stimulus condition and sequence length defining the within-subjects factors. Covariates were the previous (stimulus-recognition study) scores for the stimuli utilized on each trial. A summary of the analysis of covariance is presented in Table 4.

The analysis of covariance yielded a number of significant effects. The three main effects of age, stimulu condition, and sequence length were highly significant (Age: $F = 5.96$, 2/53 df, $p < .005$); however, the sequence-length and stimulus-condition effects showed an interaction with group. The group main effect approached significance at the .05 level (Group: $F = 3.89$, 1/53 df, $p. < .054$).

The analysis confirmed the trends which were evident in Tables 2 and 3. First, span increase with age was very evident from the means. For the nonretarded children, the increases were totally consistent, since all comparisons between progressive ages revealed higher mean scores at the higher age. The retarded students showed only slightly less consistency: nine of the 12 comparisons between progressive ages revealed higher mean scores at the higher age. Second, the retarded students scored lower than the nonretarded children on almost all (eight of nine) comparisons when the stimuli were linguistic. They scored more like the nonretarded children when the stimuli were perceptual: on

Table 2

Means and Standard Deviations (SDs) of Items Recalled in the Recognition Memory-Span Task: Linguistic Stimuli

Group	Number of subjects	Sequence length 2 Mean	2 SD	4 Mean	4 SD	6 Mean	6 SD
Developmental age[a] three							
Retarded	11	1.07	.22	1.45	.56	1.78	.50
Nonretarded	9	1.47	.28	1.56	.28	1.78	.49
Developmental age[a] four							
Retarded	14	1.31	.28	1.30	.35	1.99	.49
Nonretarded	6	1.67	.24	1.87	.50	2.10	.50
Developmental age[a] five							
Retarded	10	1.40	.23	1.66	.42	2.02	.50
Nonretarded	10	1.58	.20	1.76	.26	2.18	.49

Means over sequence length and age: Retarded $\bar{X}$ = 1.55
Nonretarded $\bar{X}$ = 1.76

[a]Developmental age was equivalent to CA for the nonretarded subjects, to MA for the retarded subjects.

Table 3

Means and Standard Deviations (SDs) of Items Recalled in the Recognition Memory-Span Task: Perceptual Stimuli

Group	Number of subjects	Sequence length 2 Mean	2 SD	4 Mean	4 SD	6 Mean	6 SD
Developmental age[a] three							
Retarded	11	1.09	.16	1.36	.45	1.98	.30
Nonretarded	9	1.09	.25	1.38	.27	1.51	.38
Developmental age[a] four							
Retarded	14	1.07	.22	1.50	.31	1.81	.32
Nonretarded	6	1.40	.13	1.53	.45	1.80	.31
Developmental age[a] five							
Retarded	10	1.32	.19	1.72	.34	2.00	.31
Nonretarded	10	1.40	.23	1.68	.36	1.92	.33

Means over sequence length and age: Retarded $\bar{X}$ = 1.53
Nonretarded $\bar{X}$ = 1.52

[a]Developmental age was equivalent to CA for the nonretarded subjects, to MA for the retarded subjects.

Table 4

Summary of the Analysis of Covariance for the Recognition Memory-Span Study

Source	SS	df	MS	F	p <
P (Group)	20.078	1	20.078	3.89	
A (Dev. Age)	61.532	2	30.766	5.96	.005
P x A	17.106	2	8.553	1.66	
Covariate	1.733	1	1.733	.34	
Error	273.537	53	5.161		
R (Stimulus condition)	38.841	1	38.841	14.74	.0001
R x A	3.185	2	1.592	.60	
R x P	34.215	1	34.215	12.98	.001
R x A x P	3.674	2	1.837	.70	
Covariate	5.278	1	5.278	2.00	
Error	139.698	53	2.636		
S (Sequence length)	31.621	2	15.811	5.25	.01
S x A	2.206	4	.552	.18	
S x P	26.170	2	13.085	4.35	.05
S x A x P	9.758	4	2.439	.81	
Covariate	.030	1	.030	.01	
R x S	5.501	2	2.780	1.11	
R x S x A	5.572	4	1.393	.56	
R x S x P	1.666	2	.833	.33	
R x S x A x P	11.855	4	2.964	1.19	
Covariate	1.692	1	1.692	.68	
Error	267.556	107	2.500		

five of the nine comparisons their mean span equalled or exceeded the nonretarded children's. These results were reflected in the highly significant group x condition interaction. Third, excepting three out of 27 comparisons involving retarded students, memory-span scores favored the linguistic stimuli. Fourth, span size increased with longer lists over the three lengths utilized in the study.

The stimulus condition x group interaction is illustrated in Figure 6 in which mean scores were summed over age and sequence length. Further analyses by group revealed that, for the nonretarded children, the mean score differences between the linguistic and perceptual stimulus conditions was highly significant ($F = 8.55$, 1/23 df, $p < .008$) favoring the linguistic stimuli. For the retarded students, the mean scores under the two conditions did not differ significantly. Individual means comparisons by stimulus condition revealed that the nonretarded children were superior to the retarded children when the stimuli were linguistic ($t_{(58)} = 16.63$, $p < .001$). When the stimuli were perceptual, the nonretarded and retarded children's scores did not differ significantly.

The sequence length x group interaction is illustrated in Figure 7 in which scores were summed over age and stimulus presentation condition. The figure reveals two unexpected results. First, the usually strong decrease in span size with longer lists was not found, as indeed had been evident from Tables 2 and 3. Second, the retarded students' scores showed the opposite effect, namely, improvement as the lists increased in length. This finding cannot reflect warm-up effects since the subjects took all list lengths in one test session and then again all list lengths, in the alternate stimulus condition, during another test session.

When compared with the findings from other studies, the curves in Figure 7 may, rather, reflect a lowering of performance at the two shorter sequence lengths, and a tendency by both groups to score near their typical performance at the longest sequence length, as reported in other studies. For example, Huttenlocher and Burke's (1976) four-hear-old children reached a mean recall score of approximately three items at sequence length 4 and a mean of

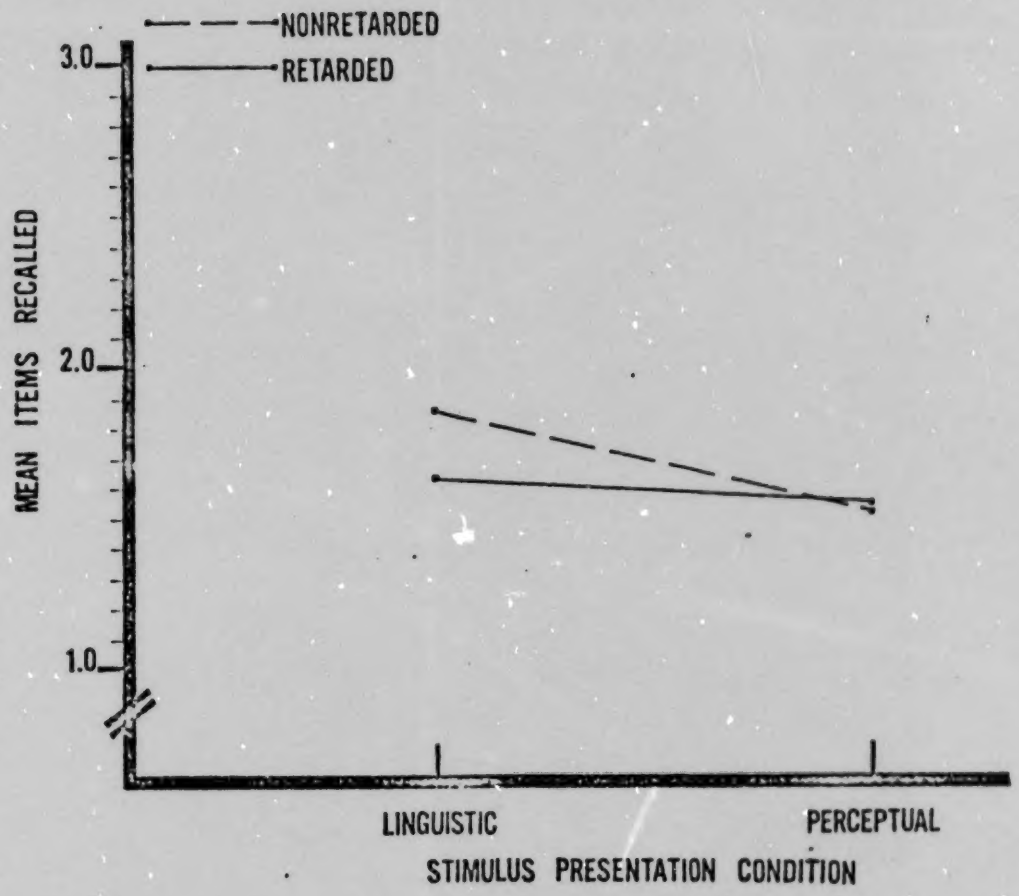


Figure 6. Recognition recall for familiar auditory stimuli by retarded and nonretarded students as a function of stimulus mode.

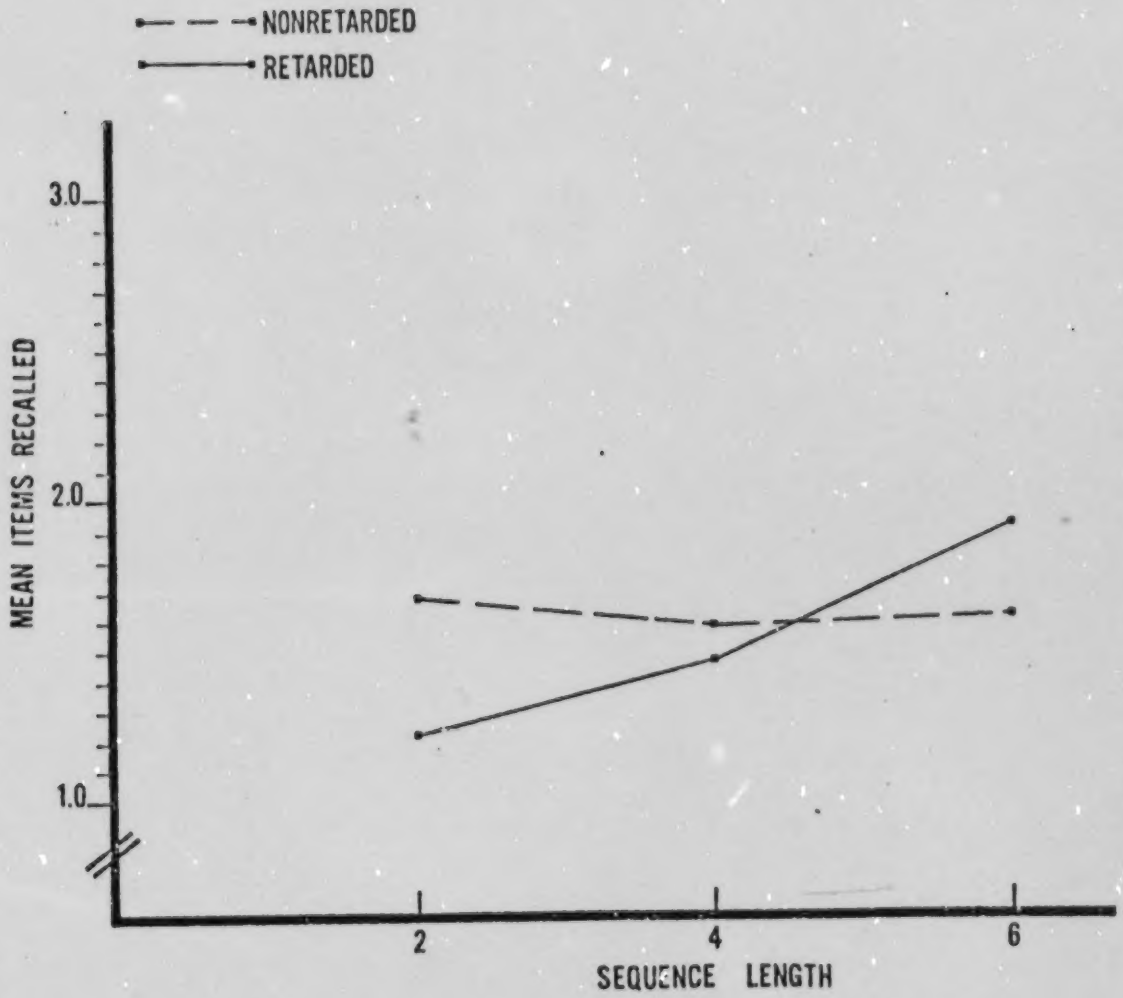


Figure 7. Recognition recall for familiar auditory stimuli by retarded and nonretarded students as a function of sequence length.

approximately 1.25 items at sequence length 6. Retarded students' mean recall score at sequence lengths varying from 3 to 12 was reported to be constant at slightly above two items (cf. Ellis, p. 6).

One-way analyses revealed that the mean increase in recall scores with increase in sequence length was highly significant for the retarded students ($F = 8.39$, 2/67 df, $p < .001$). For the nonretarded children, sequence length was not a significant factor in recognition recall.

Since the F value for main effect of age was significant, individual comparisons were computed using the Newman-Keuls method. These comparisons yielded two significant differences: the mean scores of children of developmental age three were significantly less than the scores of children ages four and five ($p < .01$). The scores of children age four and five did not differ significantly.

Response Time

Number of cases, means, and standard deviations for students' response time at each sequence length and developmental age level are presented in Tables 5 and 6, for the linguistic and perceptual stimulus conditions, respectively. Response time is given in seconds, and the means represent the sums of response times over five trials at each given sequence length.

The data were subjected to a 2 (group) x 3 (Age) x 2 (Condition) x 3 (Sequence Length) repeated measures analysis of variance, with age and group defining the between-subjects factors and stimulus condition and sequence length the within-subjects factors. The analysis-of-variance summary table is presented in Table 7. The analysis yielded highly significant main effects of group ($F = 19.94$, 1/54 df, $p < .0001$) and sequence length; however, sequence length was involved in an interaction with the group factor. The main effects of age and stimulus condition were not significant, and neither was involved in any significant interaction.

Table 5

Response Time in Recognition Memory-Span Task: Linguistic Stimuli

Group	Number of subjects	Sequence length 2 Mean	2 SD	4 Mean	4 SD	1 Mean	1 SD
Developmental age[a] three							
Retarded	11	34.39	20.91	71.37	25.38	98.03	33.26
Nonretarded	9	17.12	9.48	42.73	19.35	52.48	27.85
Developmental age[a] four							
Retarded	14	30.33	31.29	69.51	42.91	102.31	95.52
Nonretarded	6	11.30	9.77	40.43	23.22	56.02	30.80
Developmental age[a] five							
Retarded	10	18.67	8.19	61.89	26.95	93.42	35.59
Nonretarded	10	9.38	3.23	37.27	16.71	42.13	13.38

Note. Response time in seconds, summed over five trials.

[a]Developmental age was equivalent to CA for the nonretarded subjects, to MA for the retarded subjects.

Table 6

Response Time in Recognition Memory-Span Task: Perceptual Stimuli

Group	Number of subjects	Sequence length 2 Mean	2 SD	4 Mean	4 SD	6 Mean	6 SD
Developmental age[a] three							
Retarded	11	35.35	11.42	77.50	22.31	99.96	31.64
Nonretarded	9	25.91	10.75	48.56	13.12	57.27	26.67
Developmental age[a] four							
Retarded	14	32.36	23.60	70.15	25.58	104.92	47.40
Nonretarded	6	16.15	7.23	44.63	10.25	51.65	19.45
Developmental age[a] five							
Retarded	10	27.40	12.74	66.37	24.44	75.84	23.34
Nonretarded	10	15.30	5.83	39.92	10.11	49.57	11.81

Note. Response time in seconds, summed over five trials.

[a]Developmental age was equivalent to CA for the nonretarded subjects, to MA for the retarded subjects.

Table 7

Summary of the Analysis of Variance for Response Time in the Recognition Memory-Span Study

Source	SS	df	MS	F	p<
A (Age)	680,256.0	2	340,128.00	.99	
P (Group)	6,824,528.0	1	6,824,528.00	19.94	.0001
A x P	60,128.0	2	30,064.00	.09	
Error	18,458,152.0	54	342,317.63		
R (Stimulus condition)	65,168.0	1	65,168.00	.84	
R x A	16,634.0	2	8,317.00	.00	
R x P	23,679.0	1	23,679.00	.31	
R x A x P	16,747.0	2	8,373.50	.11	
Error	4,178,323.0	54	77,376.31		
S (Sequence length)	14,966,763.0	2	7,483,381.00	154.60	.0001
S x A	101,226.0	4	25,306.50	.52	
S x P	1,300,492.0	2	650,246.00	13.43	.0001
S x A x P	22,569.0	4	5,642.25	.12	
Error	5,227,669.0	108	48,404.34		
R x S	58,063.0	2	29,031.50	1.25	
R x S x A	32,053.0	4	8,013.25	.35	
R x S x P	15,382.0	2	7,691.0	.33	
R x S x A x P	126,822.0	4	31,705.00	1.37	
Error	2,502,721.0	108	23,173.34		

As might be expected, all children required more time to complete the trials at the longer sequence lengths than the trials at the shorter sequence lengths. For the retarded students, the mean difference in response time between the longest and shortest sequence was more than 13 seconds. For the nonretarded children, the mean difference was seven seconds. The relatively sharper increase for retarded than for nonretarded subjects was reflected in the significant group x sequence length interaction.

Another predictable result was seen in the main effect of group, with the retarded students requiring consistently and substantially longer time to make their response. As Tables 5 and 6 show, they typically needed about twice as much time as did the nonretarded children.

Although the tables reveal a consistent trend toward shorter response times at each increasing developmental age level, for all children and under both stimulus conditions, this effect was not statistically reliable as seen by the absence of a main or interaction effect of age. The absence of a main or interaction effect of stimulus condition was a highly logical, though not explicitly anticipated, result. Two different stimuli for the same experiential even--if the stimuli are equally effective in mediating knowledge of the event--should lead to similarly expedient identification given choices as in the present task.

The sequence length x group interaction is illustrated in Figure 8 in which response time was summed over age and stimulus condition, but was not summed over trials. The curves reveal also the greatly elevated response time for the retarded students at all sequence lengths, relative to the nonretarded subjects. Further analysis showed the general increase in response time with sequence length to be highly significant for both groups (Retarded: $F = 118.09$, 2/68 df, $p < .0001$; Nonretarded: $F = 93.61$, 2/48 df, $p < .0001$). Newman-Keuls follow-up computations yielded two significant differences, for both the retarded and for the nonretarded subjects. For both groups, response time at sequence length 2 was less than response time at sequence length 4 ($p < .01$). Likewise, for both groups response time at sequence length 4 was less than response time

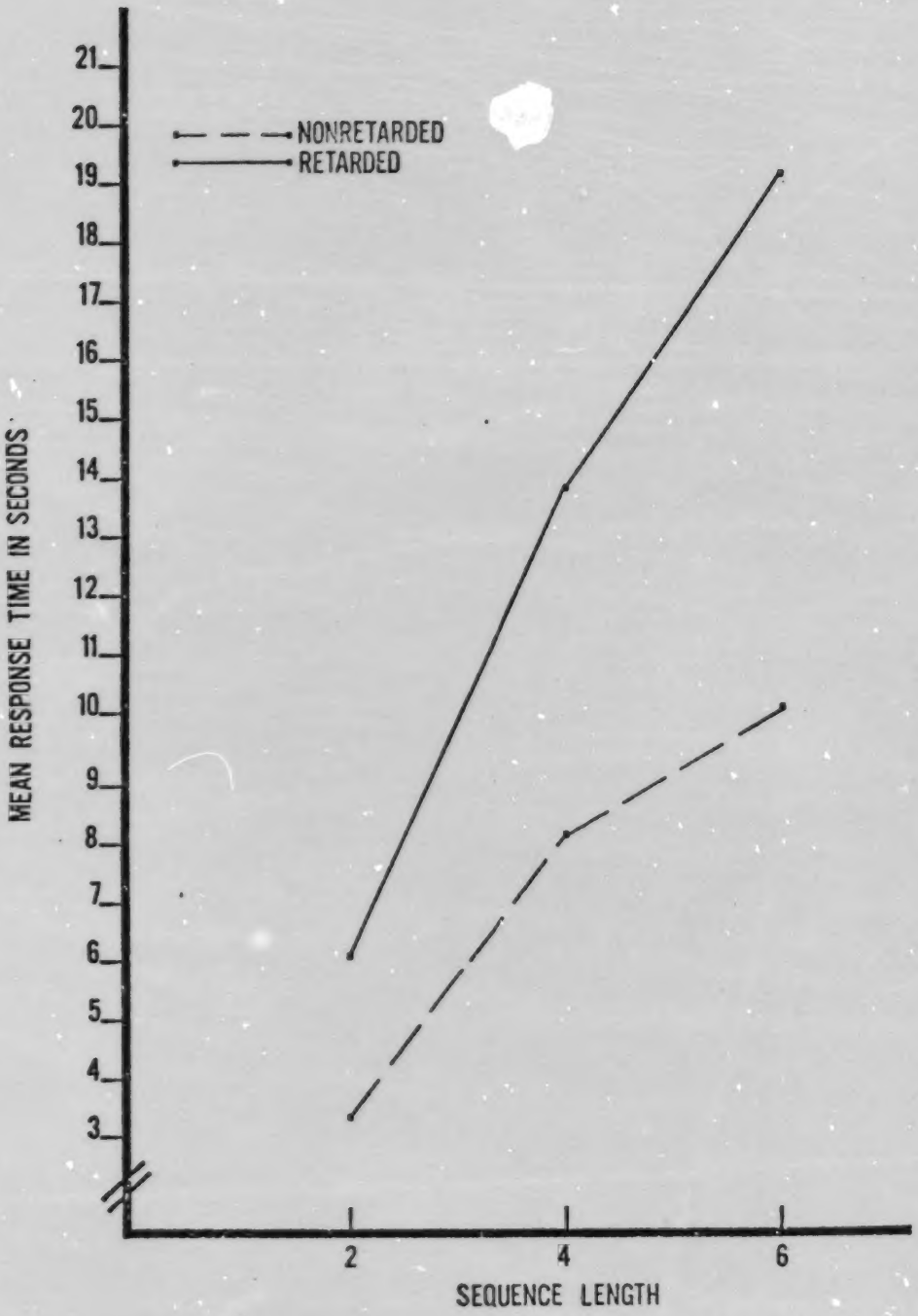


Figure 8. Response time by retarded and nonretarded students as a function of sequence length.

at sequence length 6 ($p < .01$). Individual means comparisons for the retarded and nonretarded differed profoundly at each sequence length. The t values were 240.15, 551.44, and 625.89 at sequence lengths 2, 4, and 6, respectively, all of which were significant beyond the .0001 level.

Summary and Conclusions

In terms of the research questions raised earlier, the data from this study (a) provided strong evidence that auditory memory span increases with developmental age over the preschool years; (b) provided some evidence that, on a recognition-type auditory memory-span task retarded children can perform similarly to nonretarded children of like developmental age: and (c) provided evidence that, if auditory memory span is measured with stimuli in the perceptual or the linguistic mode, the effect of stimulus mode may vary for different children.

Not supported was the theory which considers growth of auditory memory span in young children to be an artifact of measurement with verbal rather than nonverbal stimuli. In the present study, in which both verbal and nonverbal stimuli for the same referential events were utilized, in a within-subjects design, span increase with age was highly reliable for both types of stimuli. This result indicates that span increase is not a function only of older children's greater verbal ability but may reflect more fundamental, age-related abilities in cognitive processing.

The above theory also maintains that preschool children's memory strategies progress from a predominantly perceptual basis to increasing dominance by language. As the data from the present study did not yield a significant age-and-stimulus-condition interaction, this assumption likewise was not corroborated for the memory-span task chosen.

Stimulus condition produced a strong interaction with group, however. This interaction points to the possibility that a relationship between stimulus mode and memory span, in some form as hypothesized by Olson (1973), might exist

for some children. Whereas in the present study, the more "verbal" nonretarded children achieved substantially higher recall with linguistic than with perceptual stimuli, the less verbal retarded students did not. And whereas the former children's span performance was substantially better than the retarded students' when the stimuli were linguistic, the retarded students' span performance was quite "successful," in comparison to the nonretarded children's, when the stimuli were perceptual.

Both the retarded and the nonretarded subjects' serial recall scores were somewhat lower than has been reported in other memory-span studies. Since the methodology was new, the results must be considered tentative. The conclusion is suggested that a batch-processing memory task may be more difficult for children than a straight recall or a recognition probe task, and that it may be especially so for normal young children. This argument will be elaborated in the discussion.

The respone time data from the memory study showed profound differences between the retarded and the nonretarded subjects. The former required more time for trials at any sequence length. This finding was in agreement with the results from other relevant research.

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DISCUSSION

In studies which aim at analyzing patterns of perceptual-cognitive abilities and disabilities of mentally handicapped children, and of young children in general, the design of appropriate procedures presents a serious methodological problem. The sensitivity of response outcomes to task conditions has been of considerable concern to researchers working with the mentally handicapped. For example, Longhurst and Grubbs (1974) documented differences in expressive language characteristics of retarded children which could be related directly to the methods of language elicitation. Luria (1963) drew attention to the dramatic effect on retarded children's shape-dicrimination learning when the oral instructions were concretized; Constantine and Sidman (1975) observed substantially better matching-to-sample performance by their severely retarded subjects when conditions were changed from a visual-visual to an auditory-visual task.

When characteristics of the processing of verbal and nonverbal stimuli is an object of evaluation, the nature of the response task is particularly crucial. In most clinical studies, subjects' familiarity with events represented by nonverbal auditory stimuli has been tested via picture-choice procedures. In Knox and Kumura's (1970) comparative study of children's recognition of verbal and nonverbal auditory stimuli, picture selection was, likewise, used as response task. In the only previous comparative study of children's short-term memory for verbal and nonverbal auditory stimuli, however, children were asked to repeat or describe the stimuli (Lasky et al., 1975). The outcome of that study was that the recall scores for stimuli presented in the verbal-linguistic mode were significantly higher than the recall scores for stimuli presented in the nonverbal-perceptual mode.

It appears likely that, when children's ability to process verbal versus nonverbal stimuli is being compared, choice of a verbal response task, as in the Lasky et al. study, would bias the results in favor of the linguistic

timuli. This seems suggested by the fact that words are linguistically encoded at input, and do not require recoding for oral output. The referent events represented by perceptual auditory stimuli (environmental sounds), on the other hand, must either first be coded into linguistic units or descriptions, or else mimed onomatopoetically or gesturally for vocal or manual, expressive output. But, (a) the encoding would take time and would diminish the opportunity for stimulus rehearsal by that time factor, and (b) children's ability to describe or gesturally render nonverbal stimuli would be affected by the much greater inter-stimulus variability of sounds than of words. To illustrate this last point, the perceptual auditory stimuli which represent "thunder," "parade" or "music box" would be considerably harder for a child to mimic or describe than the stimuli which represent "dog," "coughing" or "walking."

For these and other reasons, neutrality of response task to stimulus mode is a crucial factor in memory or other, stimulus-processing research involving linguistic and perceptual stimuli. In visual memory research, attempts have been made to solve this problem by presenting pictures or real objects as perceptual, and written labels as their corresponding linguistic, stimuli. Use of written words, however, greatly limits the applicability of these methods to research involving young children and mentally handicapped individuals. Butterfield and Belmont (1972) spoke to this point when they admitted of disinterest in studying the memory functions of more severely mentally handicapped persons because of the latter's inability to read. But, admittance of these limitations points to the urgent need for exploration of other methods to study children's memory ability--particularly memory for verbal and nonverbal stimulus events. The present study attempted to explore an approach to this problem, for memory research in the auditory modality.

The method utilized was evolved from Klatzky's (1975) description of procedures in the study of human memory, and statements concerning the feasibility of combining recognition and serial-learning procedures. Klatzky noted that

> a recognition test can use a batch-testing procedure, in which everything--all the list words and all the distractors--is presented at once. The subject then tries to indicate which words were on the list . . . (One can also) ask the subject to indicate which ordering of a set of items corresponded to the order in which they had previously been presented (Klatzky, 1975, p. 10).

The method developed for the present study involved a combination of the procedures indicated above. It required subjects to point to those items in the response picture set which corresponded to items in the auditory stimulus set. It entailed indication of the order of stimulus occurrence in the auditory list through subjects' order of choice of the response pictures. Flavell, Beach, and Chinsky (1966) have reported on an adaptation of the batch-processing procedure quite similar to that adopted in the present study, though these authors' involved visual-visual rather than auditory-visual matching. The subjects in the study by Flavell et al. (children in grades K, 2, and 5) were shown seven pictures, and after the experimenter had pointed to three random ones in succession, they were presented with a duplicate set of the pictures and required to "point to the same three pictures and in the same sequence (in which the experimenter) had pointed to them previously" (p. 286). Thus, the major features of the method employed in the present study--pictures, batch processing, and serial order--were also used by Flavell et al. Since this method offers an alternative to verbal reporting of stimuli, it might be particularly suited for memory research with the retarded. Most importantly for comparative study of verbal and nonverbal stimulus processing, it ensures neutrality of response task to stimulus mode.

The results of the study were not all as anticipated, and at least four general observations may be made. First, the strong age effect obtained in this study was in agreement with the findings from other research in which different memory procedures have been utilized. The present outcome provides even stronger support for the hypothesis of memory span growth with age, since the effect of age proved invariant when measured with a different experimental procedure. The question of primary interest for Flavell et al. (1966) had not been growth of span per se--which they discussed only in passing--but

growth of and effect of verbalization on recall scores with age. While the effect of age on immediate memory span had been studied extensively and appeared to be widely accepted, its general validity had recently been challenged by Olson (1973).

Second, the present study not only re-confirmed validity of the age-variable effect, under a different experimental procedure, but it documented independence of this effect from stimulus mode. This finding negates, for an auditory memory task, Olson's prediction of an interaction of age with stimulus mode. Olson's prediction was to the effect that, for younger children, perceptual stimuli would be easier to process than linguistic stimuli while this might not be true for older children. This prediction thus was negated in this research for both the earlier, stimulus-recognition task, and for the memory task, and for both normally developing and mentally handicapped children.

The third observation has strong implications for comparative research with the mentally handicapped. The interaction of group and stimulus condition showed retarded children's memory-span scores to be comparable to mental-age matched, nonretarded children's when the stimuli were perceptual. Yet the great majority of comparative memory studies, and many of those in which inferior performance by the retarded was documented, have utilized verbal stimulus materials. The results of this study suggest that it might not be memory capacity per se which is impaired in the retarded student but, rather, memory for abstract signals. When exposed to auditory signals for several distinct events, the retarded child at a given developmental level may retain these as well as the nonretarded child of similar development, if the signals resemble in physical form those which have become meaningful for him direct, real-life, sensory experiences. When the signals are words--abstracted symbols superimposed on experiences and, as it were, compressing a multitude of experiences into a single linguistic form--the retarded child may not be able to retain them as well as the nonretarded child. In this sense one might even argue that perceptual stimuli might represent the retarded person's world with <u>less</u> "chaos" than abstract linguistic stimuli, since the associations

of perceptual signals to significant experiences are more restricted, and thus more distinctive, than the associations of linguistic symbols to experience. The finding was consistent in both the (stimulus recognition and memory-span) studies funded under this grant: no performance differences between retarded and nonretarded subjects when the stimuli were perceptual, but significantly inferior performance by the retarded subjects when the stimuli were linguistic. These findings lend strong support to recent suggestions that "mediation in . . . modality systems (other than the verbal) might result in facilitated recall . . . by retarded individuals" (Conroy, 1978, p. 410). It seems possible that both research and training in memory with retarded persons might be advanced through further explorations of use of nonverbal, auditory stimulus forms.

The fourth observation concerns the apparent diminution of memory span scores under the batch-processing, recognition procedure. In contrast to the "typical" short-term memory, mean scores reported for children aged three through five--i.e., 3 items at age three and 4.5 items between ages four and five--the mean scores of children in the present study ranged from only 1.07 items for the three-year old children (shortest sequence length) to 2.18 items for the five-year-old children (longest sequence). However, lower scores were also obtained by Flavell et al. in the aforementioned study, and the results from two different studies by Flavell and his associates demonstrate well the apparently suppressive effect of the batch-processing procedure. In the study described earlier (Flavell et al., 1966), Kindergarten children obtained a mean recall score of 1.75 items, which was even slightly lower than the five-year-old children's in the present study. In contrast, the nursery-school children in the study by Flavell, Friedrichs, and Hoyt (1970) obtained a mean recall score of 3.61 items. In that study, the children had been tested in a standard serial-recall procedure (i.e., with their task being to repeat stimulus lists in correct order).

In a series of studies with adult subjects, Slamecka (1968) documented reduced recall under conditions of extensive cueing. The students received two presentations of a 30-word list at a fast presentation rate (two words per

second). The experimental subjects were given 5, 15, and eventually 25 of the 30 stimulus words and were asked to write the remaining words. The control subjects, who received only a blank answer sheet in the recall test, recalled significantly more words than the experimental subjects. Slamecka's reasoning to explain these findings applies to the findings from the present, picture-recognition task as well. He argued that the experimental subjects had to spend several seconds reading the words which they had been given, in order to determine which additional words had been contained in the stimulus list. Reading the cue words deprived them of the "quick burst of recall" for items available in primary memory at the end of the list, and for items which through rehearsal, or an account of some particularly salient perceptual feature might have been readily available. Control subjects were able to "rescue" such items before they had faded, and thus were able to retrieve more items, overall, than the experimental subjects who first had to evaluate the selective items provided.

Such a result would also, most likely, obtain in recognition-recall procedures for series of items, as in the present study. For example, assuming that the subjects were able to hold a number of stimulus items, e.g., four or five, in the short-term store, a procedure which allowed of an immediate "dump" of the entire contents of the store would likely have resulted in recall of many of these items. In contrast, the necessity to evaluate each separate picture in a large set would likely have resulted in loss of several items during the time required for the picture evaluations, and in subjects' poorer recall performance, consequently. It is possible, furthermore, that the non-retarded children's recall performance was more adversely affected than the retarded students'. The latter are not found to recall at a much higher level under other recall procedures, whereas nonretarded children typically are.

Finally, then, the batch-processing, recognition procedure may not be the most ideal method to study memory performance in developmentally young learners, if determination of size of span at different ages is the question of primary research interest. Although it reflects the effects of some variables which

have been found to influence memory span, e.g., age, it may distort the effects of others. For example, decrease of span scores with increasingly longer lists, when memory span is exceeded, has consistently been obtained with other methods but was not found in this study. Further exploration of batch-processing procedures appears desirable, however, in the light of their usefulness in research with children, when nonverbal stimulus materials are employed. Use of the latter, in turn, may enable researchers to learn more about cognitive competencies and processes of the more severely mentally handicapped, which have not been extensively investigated in the past.

Limitations of the Studies, and Suggestions for Further Research

Lack of psychometric test information on the nonretarded children was an obvious limitation of the present study. Results of the comparative analyses can therefore only be considered suggestive. Nonavailability of stimulus norms is another limiting factor. In both the present and the earlier, stimulus-recognition study, an attempt to control for effects of acoustic stimulus variation (for the perceptual stimuli) was made only for the dimension of duration. However, even within the duration dimension the stimuli showed certain variability. Some sounds are naturally continuous beyond the specific recorded time segment (three seconds) while others come to a natural termination within this segment. A potential effect of perceived continuation versus natural termination of sounds is only one example of uncontrolled factors relating to acoustic properties of the perceptual stimuli. In none of the very few studies which as yet have utilized such stimuli have attempts at scaling the stimuli on acoustic characteristics been undertaken. Furthermore, norms concerning relative frequency of such stimuli in children's environment are as yet lacking. Possible differential impact of any of the above stimulus factors on the groups of children studied, and on children at different age levels within groups can, therefore, not be determined until such norms will be developed. Third, for the response time data, subjects' manual identification of the pictures should be mentioned as a limiting task factor. It is likely that, with the measure

of response time used, the retarded students' motoric handicaps would have caused some inflation of the difference between the groups' response time scores, though the direction of the observed difference is corroborated by considerable previous research.

It seems possible that the generally low scores, overall, in the memory study may have precluded or at least diminished a potential effect of stimulus condition on span as hypothesized by Olson. Relevant memory research with linguistic and perceptual stimuli, in the auditory stimulus modality, is as yet practically nonexistent (excepting the Lasky et al. study and the present study). It would seem desirable to also test Olson's theory with another experimental task, one that would be less prone to floor effects than the batch-processing procedure utilized in the present study apparently was. Recognition tasks with single probe pictures--or even with individual, probe sounds or words--might provide a more favorable test for the Olson theory. Possible stimulus mode effects might, furthermore, be studied profitably in long-term memory tasks.

The findings from the two experiments conducted under this grant suggest that further research with auditory, perceptual and verbal stimuli may reap benefits for the study of information processing and language learning in the more severely mentally handicapped.

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APPENDIX A

RAW DATA FROM THE RECOGNITION MEMORY-SPAN STUDY

APPENDIX A

RAW DATA FROM THE RECOGNITION MEMORY-SPAN STUDY

Codes for the data in the printout are as follows:

ID — Identification number assigned to subject; this is the same as in the Stimulus Recognition Study.

AGE — Developmental age in months.

POP — Group--retarded (2) or nonretarded (1).

S2L1-S2L5, S4L1-S4L5, S6L1-S6L5 — Simple recall scores at sequence lengths 2, 4, and 6 in linguistic stimulus condition; five trials each.

S2P1-S2P5, S4P1-S4P5, S6P1-S6P5 — Simple recall scores at sequence lengths 2, 4, and 6 in perceptual stimulus condition; five trials each.

A2L1-A2L5, A4L1-A4L5, A6L1-A6L5 — Adjusted serial recall scores at sequence lengths 2, 4, and 6 in linguistic stimulus condition; five trials each.

A2P1-A2P5, A4P1-A4P5, A6P1-A6P5 — Adjusted serial recall scores at sequence lengths 2, 4, and 6 in perceptual stimulus condition; five trials each.

TL2-TL6, TP2-TP6 — Response time at sequence lengths 2, 4, and 6 in linguistic and perceptual stimulus conditions, summed over the five trials at each sequence length; response time in tenths of seconds.

E2L1-E2L5, E4L1-E4L5, E6L1-E6L5, E2P1-E2P5, E4P1-E4P5, E6P1-E6P5 — Number of errors--1 through 5--at sequence lengths 2, 4, and 6 in linguistic and per-eptual stimulus conditions. Errors were summed over the five trials at each sequence length. Error 1 = omission, error 2 = insertion, error 3 = substitution, error 4 = reversal, error 5 = intra-list intrusion.

Subject data are read across, from left to right. Data per trial (slide) are read down, from top to bottom.

O	A 4	A 4	A 4	A 6	A 6	A 6	A 6	A 6	T	T	T	E 2	E 2	E 2	E 2	E 2	E 4	E 4	E 4	E 4	E 4	E 6	E 6	E 6	E 6	E 2	E 2	E 2	E 2	E 2	E 4	E 4	E 4	E 4	E 4	E 6	E 6	E	C 6	L 6	C 6	T	T	T
B S	P 3	P 4	P 5	P 1	P 2	P 3	P 4	P 5	L 2	L 4	L 6	L 1	L 2	L 3	L 4	L 5	L 1	L 2	L 3	L 4	L 5	L 1	L 2	L 3	L 4	L 5	P 1	P 2	P 3	P 4	P 5	P 1	P 2	P 3	P 4	P 5	P 1	P 2	P	P 3	P 4	P 5	P 2	P 4	P L
1	2	2	2	1	1	2	2	1	127	394	503	0	0	0	3	0	4	0	2	2	2	12	0	3	2	1	0	0	2	3	0	7	0	2	2	1	18	0	1	4	1	250	434	424
2	2	1	1	2	4	2	1	1	223	354	345	0	0	1	2	0	6	0	3	2	2	21	0	1	2	0	2	0	3	0	0	6	0	3	4	1	11	0	5	4	0	327	589	504
3	1	1	1	1	1	3	1	2	192	668	843	0	0	1	1	0	3	0	2	3	4	9	0	1	3	7	0	0	2	4	0	2	1	5	3	3	12	0	5	3	2	165	370	294
4	1	1	2	1	2	2	2	2	112	411	610	0	0	0	0	0	5	0	0	1	5	13	0	1	4	3	0	0	1	2	0	7	0	4	1	1	14	0	3	1	4	242	577	1030
5	2	1	0	1	0	1	1	1	.	.	.	0	0	4	1	0	14	0	1	0	0	23	0	1	0	0	2	0	3	0	0	5	0	9	0	0	13	0	9	1	3	494	506	712
6	1	2	1	2	0	2	1	2	76	491	894	0	0	0	1	0	2	0	1	2	1	6	1	2	1	6	0	0	1	1	0	7	0	3	2	0	19	0	2	2	1	55	606	369
7	1	2	2	2	3	2	1	2	110	545	678	0	0	0	1	0	0	0	5	1	4	10	0	3	3	3	0	0	0	3	0	2	0	3	2	3	9	0	5	3	3	154	463	682
8	1	2	1	2	2	1	2	0	215	492	938	1	0	1	2	0	9	0	0	2	2	14	0	1	1	3	0	1	2	1	0	5	0	6	3	0	16	0	6	2	0	277	420	729
9	2	1	1	3	2	1	1	1	332	646	426	0	0	2	1	0	6	0	5	0	1	18	0	6	0	0	0	3	3	2	0	5	0	4	2	3	13	0	5	1	1	179	473	356
10	3	1	1	2	1	2	1	2	295	647	757	0	0	0	0	0	8	0	2	2	1	15	0	2	3	2	0	0	1	2	0	8	0	2	2	0	15	0	3	2	2	285	484	824
11	1	3	1	2	1	1	1	1	192	469	627	0	0	0	2	0	9	0	2	1	0	17	0	0	3	1	1	0	2	2	0	6	0	6	1	0	20	0	2	2	0	266	721	746
12	1	1	1	3	1	2	2	1	.	.	.	0	0	1	2	0	4	0	0	2	5	7	0	1	4	3	0	0	1	2	0	7	0	2	4	2	16	0	1	3	2	115	296	407
13	2	1	2	1	2	2	1	2	165	483	427	0	0	0	2	0	8	0	1	1	2	9	0	9	3	1	0	1	1	1	0	1	0	8	0	1	17	0	4	1	0	172	280	209
14	2	3	1	2	3	3	1	1	68	273	522	0	0	0	3	0	5	0	3	2	2	6	1	4	.	4	1	0	0	2	0	1	1	2	3	3	3	1	8	3	5	114	434	509
15	2	1	1	1	3	1	2	1	222	448	930	0	0	0	2	0	7	0	0	1	0	15	0	0	0	5	1	0	0	1	0	7	0	0	4	1	13	0	0	5	4	295	557	560
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17	2	2	2	2	2	1	0	2	403	675	974	0	0	1	4	0	0	2	3	3	3	3	0	6	2	6	0	2	0	3	0	2	0	3	3	4	1	2	9	4	7	236	632	1179
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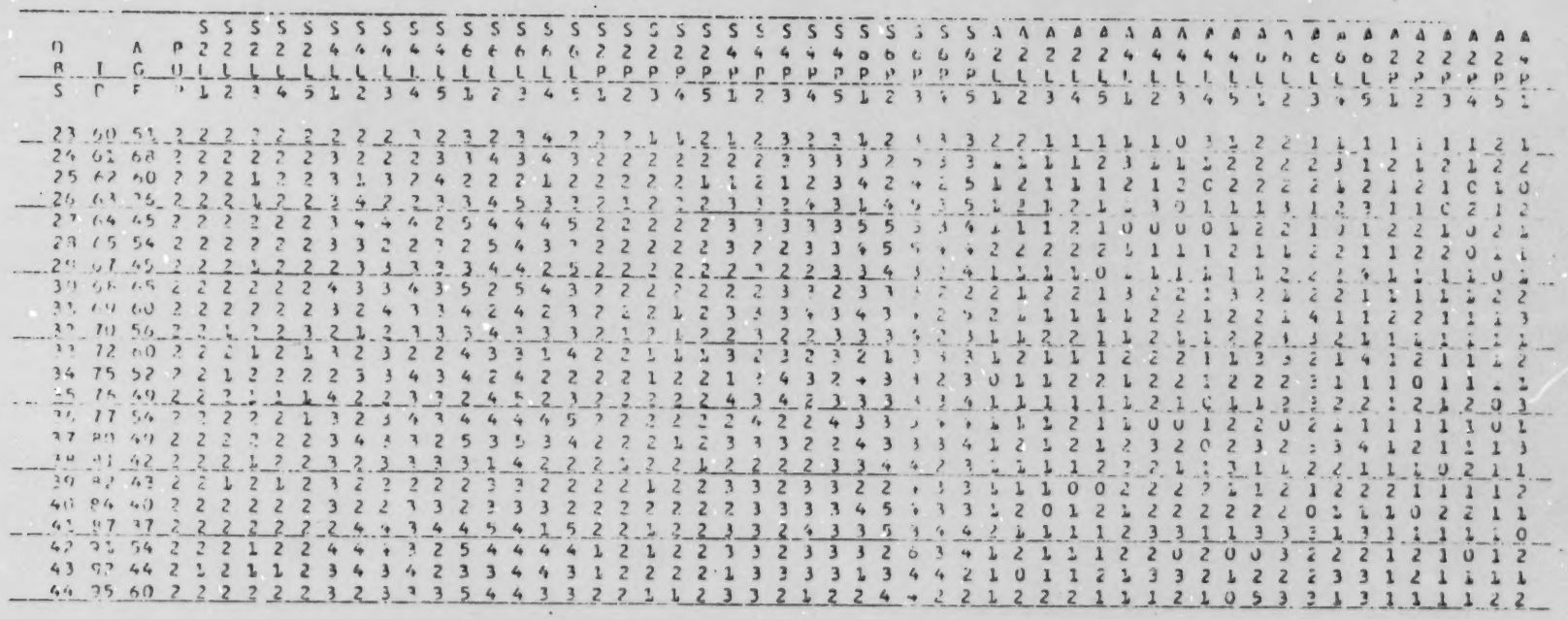
20	2	1	2	1	2	2	3	2	2315	1973	4269	0	0	2	2	0	4	1	6	3	0	9	0	7	3	1	0	2	2	1	1	3	0	6	1	2	7	0	10	2	1	1009	1245	2247
21	2	2	1	2	1	3	2	1	119	325	678	0	0	2	2	0	1	1	2	4	3	0	3	7	3	5	1	0	0	2	0	3	0	2	2	4	1	2	5	4	9	184	534	596
22	1	0	2	2	1	2	1	2	250	520	851	0	1	0	2	0	2	4	2	2	3	3	1	5	5	4	0	1	1	3	0	0	3	6	5	1	4	1	11	3	3	240	733	879



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B	I	G	U	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	6	6	6	6	6	6	6	6	6	6	6	6	6	6
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O		A	A	A	A	A	A	A	A	A				E	E	E	E	E	E	E	E	E	F	E	E	E	E	E	E	F	L	E	E	E	E	L	L	L	L	E	E	L	E	L			
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APPENDIX B

MATERIALS AND INSTRUCTIONS IN THE RECOGNITION MEMORY-SPAN STUDY

B-I Contents of the Slides in the Recognition Memory-Span Study (57)

B-II Response Recording Sheet for the Recognition Memory-Span Study (60)

B-III Instructions to Students (63)

B-IV Scoring Sheet for Determining Adjusted and Simple Recall Scores (70)

B-V Instructions for Scoring Recognition Memory-Span Responses (74)

APPENDIX B-I

CONTENTS OF THE SLIDES IN THE RECOGNITION MEMORY-SPAN STUDY

Slide Contents

Sequence Length 2:

1.	Choir	audience	dripping	cow
2.	Horn	mower	window braking	gun
3.	Knocking	baby	telephone	toothbrushing
4.	Truck	violin	sheep	cat
5.	Gun	car	yawning	carousel

Sequence Length 4:

1.	Car	water pouring	piano	coughing
	bird	violin	drum	toothbrushing
2.	Horse	walking	gun	bell
	rain	window braking	toothbrush	whistling
3.	Glass breaking	thunder	train	bath tub
	sheep	church	bird	sneezing
4.	Duck	toilet	choir	clock
	carousel	drilling	baby	violin
5.	Mower	bat	truck	walking
	cricket	guitar	bubbles	whistling

Sequence Length 6:

1.	Bat	truck	toothbrush	piano
	yawning	telephone	thunder	cat
	cow	glass	clock	rooster
2.	Baby	gun	siren	music box
	clapping	door	fizz	whistling
	cricket	horse	glass	gong
3.	Laughing	piano	church	toothbrush
	violin	car	toilet	rain
	dog	parade	mower	gun

Slide Contents (cont.)

4.	Drilling	carousel	fizz	sheep
	whistle	knocking	bird	bell
	train	cow	siren	coughing
5.	Rooster	bath tub	hammering	telephone
	jet plane	horn	drilling	cat
	cricket	bubbles	laughing	door

APPENDIX B-II

RESPONSE RECORDING SHEET (WITH DATA) FOR THE

RECOGNITION MEMORY-SPAN STUDY

AUDITORY PROCESSING

PHASE II

NAME [redacted]

SCHOOL: GP SE CHEC IDS (RVT)

ID # FROM PHASE I 74

DATES OF TESTING 4-14-78

CONDITION: LINGUISTIC (PERCEPTUAL)

TRIALS

1 (C) R O rep___

2 (C) R O rep___

3 (C) R O

4. C R O

5. C R O

6. C R O

SLIDE 1 drip cow 14

SLIDE 2 lawn mower 18

SLIDE 3 toothbrush phone 23

SLIDE 4 violin ship 29

SLIDE 5 gun yawn 16

SLIDE 6 cough drum 46

SLIDE 7 whis rain 49

SLIDE 8 train sneeze glass 45

SLIDE 9 clock drill violin 45

SLIDE 10 bubbles whis 28

SLIDE 11 thunder glass cow

47

SLIDE 12 glass door music gun

122

SLIDE 13 gun dog laugh 77

SLIDE 14 train ~~sneeze~~ cough bell 57

SLIDE 15 door laugh horn 54

APPENDIX B-III

INSTRUCTIONS TO STUDENTS

Linguistic Stimulus Condition

Perceptual Stimulus Condition

Memory Study
Instructions

Linguistic Stimulus Condition

Do you remember the last time we listened to words? You heard words and then you pointed to pictures on the screen. This time we are going to do something a little bit different. You are going to hear several words. After you have listened, you point to the pictures for all words exactly as you heard them. Let's try that.

Training Slide 1 (Laughing - hammering)

If correct: That's right. You heard the word laughing, and then hammering. (While saying this, examiner points to the pictures.) Do the next just like this one. First listen, then point to the pictures exactly as you hear the words.

If recall incorrect: I think you heard the word laughing, then hammering. Which are the right pictures for laughing and hammering? (Wait for response.) Good! That's the way you do it. First you listen to the words, then you point to the pictures exactly as you hear the words. Try the next one.

If sequence incorrect: I think you heard the word laughing first, and then hammering. (While saying this, examiner points to the pictures.) Let's try it again. After you listen to the words, point to the pictures for the words exactly as you hear them. REPEAT TRIAL.

Training Slide 2 (whistle - baby)

If correct: Good job! You heard the word whistle first, and then baby. But this time you are going to hear four words, not just two. You do it the same way. Listen first, and then point to the pictures just like you hear the words.

If recall incorrect: I think you heard the word whistle, then baby. Which are the right pictures for whistle and baby? (Wait for response.) That's right. Now try again. Listen carefully to the words, and then point to the pictures just as you hear the words.

Linguistic Stimulus Condition
(cont.)

If sequence incorrect: I think you heard the word whistle first, and then baby. (While saying this, examiner points to the pictures.) Let's try it again. After you listen to the words, point to the pictures for the words exactly as you hear them. REPEAT TRIAL.

Training Slide 3 (jetplane - telephone - baby - rooster)

If correct: Good job! You heard the words jetplane, then telephone, then baby, and then rooster. And you got them all right. You pointed to them just as you heard them. Try another one.

If recall incorrect: I think you heard the words jetplane, telephone, baby, and rooster. Which are the right pictures for jetplane, telephone, baby, and rooster? (Wait for response.) That's right. Now try again. Listen carefully to the words and then point to the pictures just as you hear the words.

If sequence incorrect: I think you heard the word jetplane first, then telephone, then baby, and then rooster. (While saying this, examiner points to the pictures.) Now listen again, and remember to point to the pictures just as you hear the words.

Training Slide 4 (mower - snoring - dripping - horn)

If correct: Fantastic! You pointed to the pictures just as you heard the words. Now you are going to hear even more words, but you point to the pictures just the same way.

If recall incorrect: I think you heard the words mower, snoring, dripping, and horn. Which are the right pictures for mower, snoring, dripping and horn? (Wait for response.) That's right. Now listen again, and then point to the pictures just as you hear the words.

Linguistic Stimulus Condition
(cont.)

If sequence incorrect: I think you heard the word mower first, then snoring, then dripping, and then horn. (While saying this, examiner points to pictures.) Now listen again, and remember to point to the pictures just like you hear the words.

Training Slide 5 (jetplane - piano - snoring - whistle - horse - bubbles)

If correct: Good word! You pointed to all the pictures just as you heard the words. I think from now on I won't say anything any more. I'll just watch you do all the rest as you did these: first listen, and then point to the pictures just as you hear the words. READY?

If recall incorrect: I think you heard the words jetplane, piano, snoring, whistle, horse, and bubbles. Which are the right pictures for jetplane, piano, snoring, whistle, horse, and bubbles? (Wait for response.) From now on, I won't say anything any more. I'll just watch you do all the rest. You do them the same way: first listen carefully, and then point to the pictures just as you hear the words.

If sequence incorrect: I think you heard the word jetplane first, then piano, then snoring, then whistle, then horse, and then bubbles. (While saying this, examiner points to the pictures.) From now on, I won't say anything any more. I'll just watch you do all the rest. You do them the same way: first listen carefully, and then point to the pictures just as you hear the words.

Memory Study
Instructions

Perceptual Stimulus Condition

Do you remember the last time we listened to sounds? You heard sounds and then you pointed to pictures on the screen. This time we are going to do something a little bit different. You are going to hear several sounds. After you have listened, you point to the pictures for all the sounds exactly as you heard them. Let's try that.

Training Slide 1 (laughing - hammering)

If correct: That's right. You heard laughing and then hammering. (While saying this, examiner points to the pictures.) Do the next just like this one. First listen, then point to the pictures exactly as you hear the sounds.

If recall incorrect: I think you heard laughing, then hammering. Which are the right pictures for laughing and hammering? (Wait for response.) Good! That's the way you do it. First you listen to the sounds, then you point to the pictures exactly as you hear the sounds. Try the next one.

If sequence incorrect: I think you heard laughing first, and then hammering. (While saying this, examiner points to the pictures.) Let's try it again. After you listen to the sounds, point to the pictures for the sounds exactly as you hear them. REPEAT TRIAL.

Training Slide 2 (whistle - baby)

If correct: Good job! You heard the whistle first, and then the baby. But this time you are going to hear four sounds, not just two. You do it the same way. Listen first, and then point to the pictures just as you hear the sounds.

If recall incorrect: I think you heard a whistle, then a baby crying. Which are the right pictures for whistle and baby? (Wait for response.) That's right. Now try again. Listen carefully to the sounds, and then point to the pictures just as you hear the sounds.

Perceptual Stimulus Condition
(cont.)

If sequence incorrect: I think you heard the whistle first, and then the baby. (While saying this, examiner points to the pictures.) Let's try it again. After you listen to the sounds, point to the pictures for the sounds exactly as you hear them. REPEAT TRIAL.

Training Slide 3 (jetplane - telephone - baby - rooster)

If correct: Good job! You heard the jetplane, then the telephone, then the baby, and then the rooster. And you got them all right. You pointed to them just like you heard them. Try another one.

If recall incorrect: I think you heard a jetplane, a telephone, a baby, and a rooster. Which are the right pictures for jetplane, telephone, baby, and rooster? (Wait for response.) That's right. Now try again. Listen carefully to the sounds and then point to the pictures just like you heard the sounds.

If sequence incorrect: I think you heard the jetplane first, then the telephone, then the baby, and then the rooster. (While saying this, examiner points to the pictures.) Now listen again, and remember to point to the pictures just as you hear the sounds.

Training Slide 5 (mower - snoring - dripping - horn)

If correct: Fantastic! You pointed to the pictures just as you heard the sounds. Now you are going to hear even more sounds, but you point to the pictures just the same way.

If recall incorrect: I think you heard a mower, snoring, dripping, and a horn. Which are the right pictures for mower, snoring, dripping and horn? (Wait for response.) That's right. Now listen again, and then point to the pictures just as you hear the sounds.

Perceptual Stimulus Condition
(cont.)

If sequence incorrect: I think you heard the mower first, then snoring, then dripping and then the horn. (While saying this, examiner points to pictures.) Now listen again, and remember to point to the pictures just as you hear the sounds.

Training Slide 6 (jetplane - piano - snoring - whistle - horse - bubbles)

If correct: Good work! You pointed to all the pictures just as you heard the sounds. I think from now on I won't say anything any more. I'll just watch you do all the rest as you did these: first listen, and then point to the pictures just as you hear the sounds. READY?

If recall incorrect: I think you heard a jetplane, a piano, snoring, a whistle, a horse, and bubbles. Which are the right pictures for jetplane, piano, snoring, whistle, horse, and bubbles? (Wait for response.) From now on, I won't say anything any more. I'll just watch you do all the rest. You do them the say way: first listen carefully, and then point to the pictures just as you hear the sounds.

If sequence incorrect: I think you heard the jetplane first, then the piano, then snoring, then the whistle, then the horse, and then bubbles. (While saying this, examiner points to the pictures.) From now on, I won't say anything any more. I'll just watch you do all the rest. You do them the say way: first listen carefully, and then point to the pictures just as you hear the sounds.

APPENDIX B-IV

SCORING SHEET FOR DETERMINING ADJUSTED AND SIMPLE RECALL SCORES

SCORING ADJUSTED RECALL

SLIDE #1.

Contents: choir audience drip cow
Stimulus: drip cow
Response: _____
Errors: o - ; in- ; s - ; e - ; ii - ;

SLIDE #2.

Contents: horn mower window gun
Stimulus: horn mower
Response: _____
Errors: o - ; in- ; s - ; e - ; ii - ;

SLIDE #3.

Contents: knock baby phone toothbrush
Stimulus: knock phone
Response: _____
Errors: o - ; in- ; s - ; e - ; ii - ;

SLIDE #4.

Contents: truck violin sheep cat
Stimulus: sheep violin
Response: _____
Errors: o - ; in- ; s - ; e - ; ii - ;

SLIDE #5.

Contents: gun car yawning carrousel
Stimulus: gun yawning
Response: _____
Errors: o - ; in- ; s - ; e - ; ii - ;

SLIDE #6.

Contents: car water piano cough bird violin drum brushing
Stimulus: water coughing bird drum
Response: _____
Errors: o - ; in- ; s - ; e - ; ii - ;

SLIDE #7.

Contents: horse walking gun bell rain window toothbrush whistling
Stimulus: horse bell rain whistling
Response: _____
Errors: o - ; in- ; s - ; e - ; ii - ;

SCORING ADJUSTED RECALL
(cont.)

SLIDE #8.
Contents: glass thunder train bathtub sheep church bird sneeze
Stimulus: train glass sneeze sheep
Response:
Errors: o - ; in- ; s - ; e - ; ii - ;

SLIDE #9.
Contents: duck toilet choir clock carrousel drill baby violin
Stimulus: duck clock drill violin
Response:
Errors: o - ; in- ; s - ; e - ; ii - ;

SLIDE #10.
Contents: mower bat truck walking cricket guitar bubbles whistling
Stimulus: walking guitar bubbles whistling
Response:
Errors: o - ; in- ; s - ; e - ; ii - ;

SLIDE #11.
Contents: bat truck brushing piano yawn phone thunder cat cow glass clock rooster
Stimulus: piano cat thunder yawn glass cow
Response:
Errors: o - ; in- ; s - ; e - ; ii - ;

SLIDE #12.
Contents: baby gun siren music clap door fizz whistling cricket horse glass gong
Stimulus: siren music clap fizz cricket gong
Response:
Errors: o - ; in- ; s - ; e - ; ii - ;

SLIDE #13.
Contents: laughing piano church toothbrush violin car toilet rain dog
Stimulus: laughing church toilet dog parade gun
Response:
Errors: o - ; in- ; s - ; e - ; ii - ;

SCORING ADJUSTED RECALL
(cont.)

SLIDE #14.

Contents: drill carrousel fizz sheep whistle knock bird bell train cow siren cough

Stimulus: fizz knock bird bell train cough

Response: _____

Errors: o - ; in- ; s - ; e - ; ii - ;

SLIDE #15.

Contents: rooster bathtub hammer phone jet horn drill cat cricket bubbles laughing door

Stimulus: rooster hammering horn drill laugh door

Response: _____

Errors: o - ; in- ; s - ; e - ; ii - ;

APPENDIX B-V

INSTRUCTIONS FOR SCORING RECOGNITION MEMORY-SPAN RESPONSES

MEMORY DATA: INSTRUCTIONS FOR SCORING

For each of 15 trials, a child has pointed to pictures on a slide which contained both the stimulus pictures and an equal number of nonstimulus pictures. The children's picture choices constitute the memory data. They are scored for two scores. (1) The simple recall score (SR) is simply the number of pictures correctly identified. (2) The adjusted serial recall score (ASR) represents a score for both correct picture identification and for the order in which they were pointed to.

On the scoring sheet, the following items are given for each trial:

Contents: lists the pictures from which the child had to choose;
Stimulus: lists the auditory stimuli which the child had heard and for which he was to choose pictures--i.e., the stimulus pictures;
Response: lists the pictures the child pointed to in order of pointing;
Errors: lists and provides room for tallying the errors which will contribute to the ASR score.

Description of Scoring

Scoring is done in the following manner.

1. SR: simply count the number of correct choices in the response. For example, if the slide contained the pictures as in the top row below (which are numbered for convenience), including stimulus pictures as in the second row and the child's response choices as in the bottom row, then the SR score would be 3.

7	3	5	8	4	6	1	2	pictures on slide
3	8	4	1					stimulus pictures
3	4	1						child's response

2. ASR: this scoring follows the procedure described by Huttenlocher and Burke.[a] From the total set of stimulus pictures--which would be four in the above example--one point is subtracted for every error in the child's response. These may be both item errors such as omission of or wrong choice for a stimulus picture and order errors such as a reversal of the order of stimulus pictures in the child's response. However,

[a] Cognitive Psychology, 1976.

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MEMORY DATA: INSTRUCTIONS FOR SCORING
(cont.)

the scoring system allows for crediting all the items on a trial which occur in a correctly ordered sequence--even if there had been an error earlier on in that trial.

Errors which result in loss of one point each are the following:

Omission	(o):	an item is left out;
Intrusion	(in):	an item is added or repeated;
Substitution	(s):	a different item is chosen;
Reversal	(e):	two directly adjoining items are reversed; that is, items which are consecutive in the response exchanged positions relative to their position in the stimulus set;
Intralist Intrusion	(ii):	an item is in a different position in the response from its position in the stimulus set, but the transposition is not a direct reversal.

Some General Illustrations of the Scoring Procedure

In these illustrations, only the pictures in the stimulus set and response are shown. Numbers are given instead of picture names, for ease of stimulus-and-response comparison. Errors are indicated by type (i.e., one of the five error types above) and, where possible, the item failed is identified.

Order of corrections:
1. omission (o)
2. intrusion (in)
3. substitution (s)
4. reversal (e)
5. intralist intrusion (ii)

Step 1. Check for omissions--missing items.
If there is an omission, cross off omitted item on stimulus list. Example:

Stimulus 7 8 ~~X~~ 9

Response 7 8 9

Errors o-4

MEMORY DATA: INSTRUCTIONS FOR SCORING
(cont.)

Step 2. Check for intrusions--extra items, including additions and repetitions. Cross out the intruded item. Example:

Stimulus 7 8 4 9

Response 7 8 ~~8~~ 4 9

Errors in-5

Once the lists have been checked for omissions and intrusions, and the proper items have been crossed off, compare the response to the stimulus to find if the remaining items are in correct order (taking into consideration the omitted or intruded items, of course). The above examples, after the "o" and "in" corrections, are in correct order, and no more corrections are necessary. If the remaining items are not in correct order after these corrections, as in the following example, further scoring is necessary. Example:

Stimulus 7 8 ~~9~~ 9

Response 8 9 7

Errors o-4

The 7 is still out of place.

Step 3. Check for substitutions.
Circle any items in the response list which are not found on the stimulus list, and cross off the item in the stimulus which has been replaced. Examples:

Stimulus 7 ~~8~~ 4 9

Response 7 (5) 4 9

Errors s-8

Stimulus 7 ~~8~~ 4 9

Response 7 4 (5) 9

Errors s-8

MEMORY DATA: INSTRUCTIONS FOR SCORING
(cont.)

A combination of an omission and a substitution is evident when two items in the stimulus are missing and there is only one omission. Examples:

Stimulus	7 ~~8~~ 4 ~~9~~
Response	7 4 (5)
Errors	o-9

The Response was checked for omissions, but there is also a substitution.

Stimulus	7 ~~8~~ 4 ~~9~~
Response	7 4 (5)
Errors	o-1; s-1

Since one cannot determine which of the two items was missed and for which the substitution was made, the errors will simply be tallied.

Again, after these corrections, check to see that the remaining items are in correct order. If they are not in correct sequential order, continue scoring.

Step 4. Check for reversals--two consecutive correct items have exchanged positions. Example:

Stimulus	7 8 4 9
Response	7 4 8 9
Errors	e-1

Step 5. Check for intralist intrusions--correct items which are out of sequential order. Example:

Stimulus	7 8 4 9 6
Response	7 9 8 4 6
Errors	ii-9

MEMORY DATA: INSTRUCTIONS FOR SCORING
(cont.)

In the above example, the 7846 in the Response are in order, and the 9 is misplaced. Another way to view the situation--complete sequential order can be restored in the Response by moving the 9 to the position between the 4 and 6. The same could be accomplished by moving the 84 to the position between the 7 and the 9 (this would only count as one move). Example:

Stimulus	7 8 4 9 6 5
Response	7 9 6 5 8 4
Errors	ii-84

The 7965 in the Response are in correct order. A move of 84 to the position between 7 and 9 would restore complete sequential order and be considered one move. Always choose the least number of moves or least penalty to subject. Example:

Stimulus	7 8 4 9 6 5
Response	7 8 6 9 4 5
Errors	ii-6; ii-4

The 6 and the 4 in the response are exchanged; however, they are not consecutive items in the stimulus and, therefore, not considered as a reversal. They are considered as two intralist intrusions (i.e., two items must be moved to restore complete sequential order to the Response list).

Some Specific Illustrations from the Data to be Scored

SLIDE #8.

Contents: glass thunder train bathtub sheep church bird sneeze
Stimulus: train glass sneeze sheep
Response: sneeze bird sheep glass train
Errors: o- ; in- 1 ; s- ; e- 1 ii- 1

The item "bird" is an intrusion. "Train" and "glass" are reversed, and they are also removed from the beginning to the end of the list. After correcting for these three errors, the remaining two items, "sneeze" and "sheep" are correct.

The SR score for this trial is: SR 4
The ASR score for this trial is (4-3): ASR 1

SLIDE #9.

Contents: duck toilet choir clock carrousel drill baby violin
Stimulus: duck clock drill violin
Response: violin toilet duck
Errors: o- ; in- ; s- 1 ; e- ii-1

One item is omitted, and there is a substitution for another one. The two items remaining are out of order. They are scored as an intralist intrusion as they are not directly adjacent.

The SR score for this trial is: SR 2
The ASR score is (4-3): ASR 1

SLIDE #13.

Contents: laughing piano church toothbrush violin car toilet rain dog parade mower gun
Stimulus: laughing church toilet dog parade gun
Response: laugh dog church gun
Errors: o- 2 ; in- ; s- ; e- 1 ; ii- ;

The SR score for this trial is: SR 4
The ASR score for this trial is (6-3): ASR 3

Some Specific Illustrations from the Data to be Scored (cont.)

SLIDE #14.

Contents:	drill carrousel fizz sheep whistle knock bird bell train cow siren cough
Stimulus:	fizz knock bird bell train cough
Response:	cough knock whistle
Errors:	o- 3 ; in- ; s- 1 ; e- 1 ; ii- ;

The SR score for this trial is: SR 2
The ASR score for this trial is (6-5) ASR 1

SLIDE #15.

Contents:	rooster bathtub hammer phone jet horn drill cat cricket bubbles laughing door
Stimulus:	rooster hammering horn drill laugh door
Response:	hammer cricket laugh door
Errors:	o- 2 ; in- ; s- 1 ; e- ; ii- ;

The SR score for this trial is: SR 3
The ASR score for this trial is (6-3): ASR 3

SLIDE #11.

Contents:	bat truck brushing piano yawn phone thunder cat cow glass clock rooster
Stimulus:	piano cat thunder yawn glass cow
Response:	thunder yawn cow clock glass
Errors:	o- 1 ; in- ; s- 1 ; e- ; ii- 1 ;

Since there is an intervening item in the response between "cow" and "glass", this order change is scored as an intralist intrusion rather than as a direct reversal.

The SR score for this trial is: SR 4
The ASR score for this trial is (6-3) ASR 3